Chapter 6
Benthic Monitoring

Introduction

The benthic monitoring program is designed to document the distribution, diversity and abundance of benthic (bottom dwelling) organisms in the upper San Francisco Estuary (Estuary). Geographic coverage of the sampling sites ranges from San Pablo Bay east through the Sacramento-San Joaquin Delta to the mouths of the Sacramento, Mokelumne, and San Joaquin rivers. The benthic community of the upper Estuary is a diverse assemblage of organisms, which includes worms, crustaceans, insects, and molluscs. This program monitors both benthic macrofauna (organisms larger than 0.5 mm) (DWR 2001) and sediment composition. General trends in sediment composition are documented at the same sites where benthic samples are collected.

The benthic monitoring program began in 1975. From 1975 through 1979 the program collected samples biannually from 11 to 16 sites. In 1980, the Department of Water Resources (DWR) revised the benthic monitoring program and began monthly sampling at five sites. In 1995, major programmatic revisions were implemented to form the current program. Since 1996, monitoring has been conducted at ten sites that are sampled monthly. The current sites represent a wide variety of habitats that vary in size and physical characteristics. Table 6-1 has site-specific information. More detailed information about the location, number, and physical characteristics of the historical sites can be found in Interagency Ecological Program (IEP) Technical Report 12 (Markmann 1986) and IEP Technical Report 38 (Hymanson et al. 1994).

Station Region	Latitude Longitude	Substrate Composition	Approx. Salinity Range (uS/cm)
C9 *Delta-Old River*	*37° 49′ 50″* *121° 33′ 09″*	*Consistent. Over 90% sand.*	*200-800*
P8 *Delta* *San Joaquin River*	*37° 58′ 42″* *121° 22′ 55″*	*Consistent. High sand content (60%)*	*175-750*
D28A *Delta* *Old River*	*37° 58′ 14″* *121° 34′ 19″*	*Mixed composition of sand and fines*	*200-350*
D16 *Delta* *San Joaquin River*	*38° 05′ 50″* *121° 40′ 05″*	*Consistent. Mostly fines with some organic materials*	*130-500*
D24 *Delta* *Sacramento River*	*38° 09′ 27″* *121° 41′ 01″*	*Consistent. High sand content (80%).*	*200-1200*
D4 *Delta* *Sacramento River*	*38° 03′ 45″* *121° 49′ 10″*	*Mixed composition of sand, fines, and organic materials.*	*130-8,000*
D6 *Suisun Bay*	*38° 02′ 40″* *122° 07′ 00″*	*Fairly equal mixture of sand and fines*	*135-30,000*
D7 *Grizzly Bay*	*38° 07′ 02″* *122° 02′ 19*	*Consistent. Mostly Fines with some organic materials.*	*200-20,000*
D41 *San Pablo Bay*	*38° 01′ 50″* *122° 22′ 15″*	*Consistent. High content of fine material (87%)*	*20,000-45,000*
D41A *San Pablo Bay*	*38° 03′ 75″* *122° 24′ 40″*	*Consistent. High content of fine material*	*30,000-44,000*

Table 6-1 Macrobenthic monitoring station characteristics, 2003

Water Right Decision D-1641 (SWRCB) requires a review of the EMP every three years "to ensure that the goals of the monitoring program are attained". The most recent programmatic review of the EMP provided plans for modifications to the benthic monitoring element. As a result, the EMP was to reduce its benthic monitoring from monthly to quarterly sampling during water years 2004 and 2005 to reserve enough resources to conduct special studies and perform a retrospective analysis of the historic EMP benthic monitoring data in order to develop a new sampling design. At the beginning of the 2003-2004 water year, the benthic monitoring program temporarily switched to quarterly sampling.

Methods

Benthic Organisms

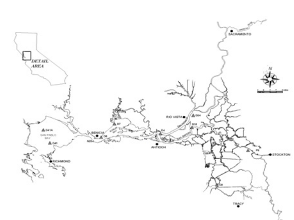

Figure 6-1 Location of 10 Environmental Monitoring Program benthic sampling sites

Field sampling was conducted at ten sites monthly, until October 2003 when the sampling regime changed to quarterly. Figure 6-1 shows the location of each site and Table 6-1 summarizes latitude and longitude, salinity range, and substrate composition for each site. The research vessel *San Carlos,* equipped with a hydraulic winch and a Ponar dredge, was used to conduct this sampling. The Ponar dredge samples a bottom area of 0.053 m^2. The contents of the dredge were washed over a Standard No. 30 stainless steel mesh screen (0.595 mm openings) to remove as much of the substrate as possible. All material remaining on the screen was preserved in approximately 20% buffered formalin containing Rose Bengal dye and transported to the laboratory for analysis. The benthic macroinvertebrate sampling methodology used in this program is described in Standard Methods for the Examination of Water and Wastewater (APHA 1998).

In the laboratory, the field preservative was decanted and the sample was washed with deionized water over a Standard No. 30 stainless steel mesh screen. Organisms were then placed in 70% ethyl alcohol for identification and enumeration. Hydrozoology[1], a private laboratory under contract with DWR, identified and enumerated organisms in the macrofaunal samples. A stereoscopic dissecting microscope (70-120X) was used to identify most organisms. When taxonomic features were too small for identification under the dissecting scope, the organism was mounted permanently on a slide and examined under a compound microscope. If more than four hours of sorting were required and a sample contained many organisms but few species, a one-fourth volume subsample was chosen at random from the sample. The subsample was sorted and the results were multiplied by four to represent the total sample. The remainder of the sample was inspected to make sure no taxa were overlooked. Individual species counts were multiplied by 19 to convert the number of organisms per grab sample to organisms per square meter (where 19 = 1.0 m^2 / 0.53 m^2 and 0.53 m^2 = sample area of the ponar).

All organisms identified and enumerated were recorded onto datasheets by Hydrozoology staff. These datasheets were returned to DWR staff for entry into the benthic monitoring program's database.

Sediment

Sediment composition samples were collected monthly in the field from the RV *San Carlos* using the same hydraulic winch and Ponar dredge used in the benthic sampling. A random subsample of the sediment was placed into a 1-liter plastic jar for storage and transported to the DWR's Soils and Concrete Laboratory for analysis.

Particle size analysis and dry weight measurements for each sediment sample were performed. Sediment was analyzed for particle size according to the American Society of Testing and Materials Protocol D422 (ASTMa 2000). Particles were sorted into the following categories: sand (>75 µm) and fine (<75 µm). Organic content of the sediment was determined using the American Society of Testing and Materials Protocol D2974, Method C (ASTMb 2000). For this method, the ash-free dry weight of the sample was used to determine the organic content of the sediment.

[1] Hydrozoology. P.O. Box 682, Newcastle, CA 95658

Results

Benthic Organisms

The benthic monitoring program collects a large number of organisms, but a relatively small number of species. Of the 180 species, ten species represented 90 percent of all organisms collected. Listed below, these species were also the ten numerically dominant species during the 2003 reporting period.

Numerically Dominant Species

Amphipods

Americorophium stimpsoni
Americorophium spinicorne
Corophium alienense
Monocorophium acherusicum
Ampelisca abdita
Gammarus daiberi

Cumacean Crustacean

Nippoleucon hinumensis

Aquatic Oligochaete (phylum Annelida)

Varichaetadrilus angustipenis

Asian Clams

Potamocorbula amurensis
Corbicula fluminea

Of the 10 dominant species, four species, *Ampelisca abdita*, *Nippoleucon hinumensis, Monocorophium acherusicum,* and *Corbula amurensis,* represent macrofauna that inhabit a typically high saline environment and were found in San Pablo Bay, Suisun Bay, and Grizzly Bay. The amphipods *Corophium alienense, Americorophium stimpsoni* and *Americorophium spinicorne* tolerate a wider range of salinity. They were collected both in the higher saline western sites and the more brackish to fresh water eastern sites, such as the San Joaquin River at Twitchell Island and the Sacramento River above Point Sacramento. The remaining three species, *Gammarus daiberi*, *Varichaetadrilus angustipenis,* and *Corbicula fluminea,* are predominantly freshwater species and were collected at sites east of Suisun Bay.

Data Management and Summarization

The EMP maintains a database containing all information on benthic organisms identified within the upper Estuary. This database continuously undergoes peer review and updating. When a new organism is found at any of the sampling sites, the organism is identified to the lowest possible taxonomic level and added to the database. Sixteen new organisms were added to the benthic species list during 2003. These new organisms were found at 4 of the 10 monitoring sites. One species was found near the Clifton Court Forebay, a freshwater site in the south Delta. Four species were found near the city of Rio Vista, a freshwater site on the Sacramento River. Eleven species were found in San Pablo Bay, a saline to brackish-water region with two sites west of the Delta. Table 6-2 lists the new species,

Phylum	Genus Species	Date	Station
Annelida	Aricidea species A	Feb-03	D41
Annelida	Tharyx parva	Feb-03	D41
Annelida	Pholoides aspera	Feb-03	D41
Arthropoda	Tipula species a	Feb-03	D24
Arthropoda	Hygrobates species A	Feb-03	D24
Arthropoda	Psychoda species A	Mar-03	D24
Arthropoda	Neoplasta species A	Mar-03	D24
Annelida	Arcteonais lomondi	Apr-03	C9
Arthropoda	Simulium Species A	May-03	D41A
Arthropoda	Callianassa species A	May-03	D41
Arthropoda	Cancer magister	May-03	D41
Arthropoda	Ampithoe valida	Jul-03	D41
Arthropoda	Monocorophium uenoi	Jul-03	D41, D41A
Annelida	Pista pacifica	Sep-03	D41
Mollusca	Melanochlamys diomedea	Sep-03	D41
Mollusca	Macoma species A	Sep-03	D41

Table 6-2 New species, 2003

locations, and the date when they were found. All data is available at http://www.baydelta.ca.gov.

All organisms collected during 2003 fell into eight phyla:

- Cnidaria (hydras, sea anemones)
- Platyhelminthes (flatworms)
- Nemertea (ribbon worms)
- Nematoda (roundworms)
- Annelida (segmented worms)
- Arthropoda (aquatic insects, amphipods, isopods, shrimp, crabs, mites, etc.)
- Mollusca (clams, snails)
- Chordata (tunicates)

Of the eight phyla identified, Annelida, Arthropoda, and Mollusca constituted 99.4% of the organisms collected during the study period. Figure 6-2 shows the total percent contribution by phylum for all sites. Figures 6-3 through 6-7 show the total contribution by phylum for each site and organism abundance for each site.

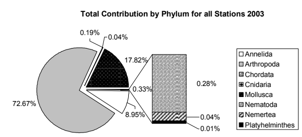

Figure 6-2 Total contribution by phyla for all stations during 2003

Organism abundance (organism per meter squared or org/m^2) and dominant phyla varied between sites. Temporal changes in organism abundance (for example, intra- and interannual) also varied greatly between sites. These variations and trends (for example, maximum, minimum, abundance, dominant species, and seasonal patterns) will be discussed for each individual site (Figures 6-3 through 6-7). Sediment composition is also discussed for each site (Figures 6-8 through 6-17).

Site C9: Benthic Abundance

Maximum abundance in 2003 occurred in June with a total of 44,565 organisms per meter squared (Figure 6-3). *Americorophium stimpsoni* (30,158 org/m^2) and *Gammarus daiberi* (12,835 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in February with a total of 442 organisms per meter squared. *Corbicula fluminea* (219 org/m^2) and *Varichaetadrilus angustipenis* (157 org/m^2) were the dominant species.

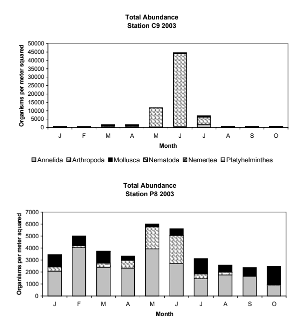

Figure 6-3 Benthic abundance at stations C9 and P8, 2003

This site demonstrated a clear seasonal pattern with the highest abundance values recorded during the spring and early summer and the lowest values recorded during the winter and fall. The 2001-2002 reporting period exhibited similar abundance patterns as those observed in 2003, with higher values in the spring and lower values in the winter and the same organism, *Americorophium stimpsoni,* as the most abundant.

Site P8: Benthic Abundance

Maximum abundance in 2003 occurred in May with a total of 6,019 organisms per meter squared (Figure 6-3). The dominant species were *Limnodrilus hoffmeisteri* (1,710 org/m^2), *Chironomus attenuatus* (1,245 org/m^2), and *Ilyodrilus frantzi* (993 org/m^2). The minimum abundance in 2003 occurred in September with a total of 2,384 organisms per meter squared. The dominant species were *Varichaetadrilus angustipenis* (637 org/m^2), *Corbicula fluminea* (618 org/m^2), and *Limnodrilus hoffmeisteri* (328 org/m^2).

This site demonstrated a seasonal pattern with the highest abundance values in the late spring and early summer and the lowest values in the late summer and fall. The annelid population is relatively stable at this site, while the arthropod population fluctuates dramatically and is the cause of the two highest peaks throughout the year.

The 2001-2002 reporting period did not demonstrate any clear interannual or intra-annual abundance patterns. This site was dominated by annelids, with the exception of the late spring and early summer months of 2002 when amphipods dominated.

Site D28A: Benthic Abundance

Maximum abundance in 2003 occurred in June with a total of 9,329 organisms per meter squared (org/m^2) (Figure 6-4). *Gammarus daiberi* (2,199 org/m^2), *Cyprideis* species *A* (1,952 org/m^2) and *Limnodrilus hoffmeisteri* (1,387 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in August with a total of 1,121 organisms per meter squared. *Corbicula fluminea* (342 org/m^2), *Varichaetadrilus angustipenis* (233 org/m^2), and *Pristina breviseta* (119 org/m^2) were the dominant species.

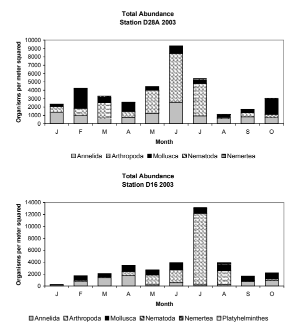

Figure 6-4 Benthic abundance at stations D28A and D16, 2003

This site demonstrated a clear seasonal pattern, with highest abundance occurring in the spring and early summer. Abundance remained moderate (< 4,000 org/m^2) for the remaining months. Amphipods were the dominant organisms during peak abundance at this site. During the remaining months, when abundance was low to moderate, annelids and clams were the dominant organisms. The 2001-2002 reporting period exhibited similar abundance and organism composition patterns as the 2003 reporting period.

Site D16: Benthic Abundance

Maximum abundance in 2003 occurred in July with a total of 13,101 organisms per meter squared (Figure 6-4). *Americorophium spinicorne* (8,104 org/m^2), *Gammarus daiberi* (3,330 org/m^2), and *Corbicula fluminea* (860 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in January with a total of 285 organisms per meter squared. *Varichaetadrilus angustipenis* (186 org/m^2) and *Corbicula fluminea* (72 org/m^2) were the dominant species.

Abundance values at this site were moderate (< 4,000 org/m^2) and fairly stable, with the exception of a peak in July. This peak was dominated by amphipods, as were the late spring and summer months.

The 2001-2002 reporting period demonstrated a seasonal pattern with low abundance during the late fall and winter and higher values during the summer and early fall. During 2001-2002 this site was dominated by amphipods.

Site D24: Benthic Abundance

Maximum abundance in 2003 occurred in May with a total of 21,109 organisms per meter squared (Figure 6-5). *Americorophium stimpsoni* (17,499 org/m^2) and *Corbicula fluminea* (2,005 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in October with a total of 3,791 organisms per meter squared. *Corbicula fluminea* (1,976 org/m^2) and *Americorophium stimpsoni* (1,544 org/m^2) were the dominant species.

Abundance was stable at this site (>12,000 org/m^2) with the exception of two spikes that occurred during May (21,109 org/m^2) and June (17,328 org/m^2). These two peaks were dominated by the amphipod *Americorophium stimpsoni.* The 2001-2002 reporting period exhibited patterns similar to those observed in the 2003 reporting period. Abundance values remained fairly constant, with the exception of a few spikes. This site was dominated by amphipods during 2001-2002.

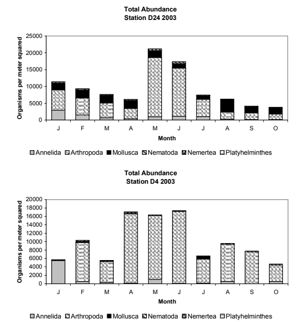

Figure 6-5 Benthic abundance at stations D24 and D4, 2003

Site D4: Benthic Abundance

Maximum abundance in 2003 occurred in June with a total of 17,347 organisms per meter squared (Figure 6-5). *Americorophium spinicorne* (15,352 org/m^2) and *Gammarus daiberi* (1,796 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in October with a total of 4,622 organisms per meter squared. *Americorophium spinicorne* (2,931 org/m^2) and *Gammarus daiberi* (1,007 org/m^2) were the dominant species.

Station D4 exhibited a seasonal pattern of higher abundance values during the spring and early summer months and lower abundance during the other months. *Americorophium spinicorne*, an amphipod, was the overall dominant organism at this site. The 2001-2002 reporting period exhibited values similar to the current reporting period. *Americorophium spinicorne* was also the dominant organism for this site during 2001-2002.

Site D6: Benthic Abundance

Maximum abundance in 2003 occurred in October with a total of 13,514 organisms per meter squared (Figure 6-6). *Potamocorbula amurensis* (13,049 org/m^2) was the dominant species. The minimum abundance in 2003 occurred in March with a total of 4,066 organisms per meter squared. *Nippoleucon hinumensis* (2,931 org/m^2) and *Potamocorbula amurensis* (1,112 org/m^2) were the dominant species.

The invasive Asian clam, *Potamocorbula amurensis,* was the dominant species found at this site. The cumacean, *Nippoleucon hinumensis*, became the dominant species during the spring.

The 2001-2002 reporting period exhibited similar abundance and organism composition patterns as those observed in the 2003 reporting period.

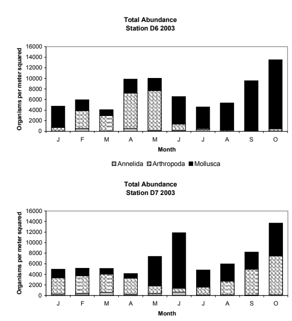

Figure 6-6 Benthic abundance at stations D6 and D7, 2003

Site D7: Benthic Abundance

Maximum abundance in 2003 occurred in October with a total of 13,718 organisms per meter squared (Figure 6-6). *Corophium alienense*

(7,306 org/m^2) and *Potamocorbula amurensis* (6,204 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in April with a total of 4,157 organisms per meter squared. *Corophium alienense* (1,748 org/m^2), *Nippoleucon hinumensis* (1,307 org/m^2) and *Potamocorbula amurensis* (884 org/m^2) were the dominant species.

During 2003 the abundance was relatively stable with the exception of June (11,875 org/m^2) and October (13,718 org/m^2). In June the Asian clam *Potamocorbula amurensis* was dominant and in October *Potamocorbula amurensis* and *Corophium alienense* were dominant.

The 2001-2002 reporting period was very dynamic. During 2001, site D7 exhibited a seasonal pattern, with the highest values occurring in the fall and winter and the lower values during the spring. During 2002, the highest values were in the late summer and fall and the lower values during the winter and spring. For both reporting periods, 2001-2002 and 2003, the mollusc population appears to be stable, while changes in overall abundance at this site are due to fluctuations in the arthropod populations.

Site D41: Benthic Abundance

Maximum abundance in 2003 occurred in July with a total of 57,589 organisms per meter squared (Figure 6-7). *Monocorophium acherusicum* (26,201 org/m^2) and *Ampelisca abdita* (22,325 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in March with a total of 2,100 organisms per meter squared. *Ampelisca lobata* (409 org/m^2), *Cirriformia spirabrancha* (399 org/m^2), *Tubificoides wasselli* (290 org/m^2), and *Diadumene* sp. *A* (285 org/m^2) were the dominant species.

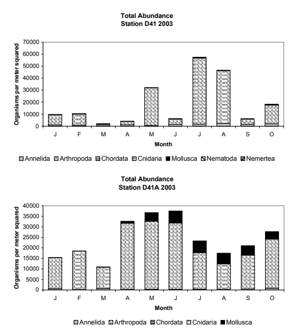

Figure 6-7 Benthic abundance at stations D41 and D41A, 2003

This site exhibits a seasonal pattern with the highest abundance during the late summer and the lowest abundance occurring during the winter and early spring. Two large spikes in population occurred during the study period. These spikes occurred in May (32,243 org/m^2), July (57,589 org/m^2), and August (46,669 org/m^2). This station was dominated by arthropods. The 2001-2002 reporting period exhibited similar abundance and organism composition patterns as those observed in the 2003 reporting period.

Site D41A: Benthic Abundance

Maximum abundance in 2003 occurred in June with a total of 37,463 organisms per meter squared (Figure 6-7). *Ampelisca abdita* (28,044 org/m^2), *Potamocorbula amurensis* (5,581 org/m^2), *Monocorophium acherusicum* (1,876 org/m^2), and *Nippoleucon hinumensis* (1,501 org/m^2) were the dominant species. The minimum abundance in 2003 occurred in March with a total of 10,911 organisms per meter squared. *Ampelisca abdita* (6,669 org/m^2) and *Nippoleucon hinumensis* (2,926 org/m^2) were the dominant species.

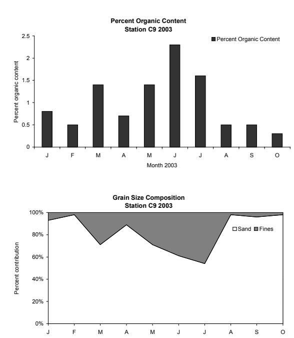

Figure 6-8 Sediment organic content and grain size at Station C9 during 2003

This site exhibits a seasonal pattern with the highest abundance occurring during the spring and early summer. This site is dominated by arthropods, but molluscs appear during the summer and fall. The 2001-2002 reporting period exhibited similar abundance and organism composition patterns as those observed in the 2003 reporting period.

Sediment

Site C9: Sediment Composition

Sand was the dominant sediment type at site C9 for 2003 (Figure 6-8). The percentage of organic content is relatively low (< 2.5%) and ranges from 0.3% to 2.3%. Higher measurements of organic matter coincide with higher amounts of finer sediments, both of which occurred during the summer.

During the 2001-2002 reporting period, site C9 exhibited similar sediment composition patterns as the 2003 reporting period.

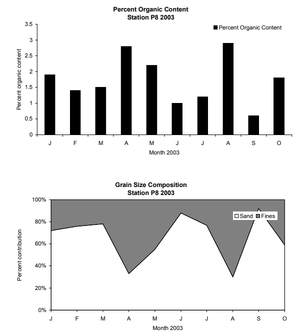

Figure 6-9 Sediment organic content and grain size at Station P8 during 2003

Site P8: Sediment Composition

Sand dominated the sediment at site P8 for most of 2003, with a pulse of finer sediments appearing every few months (Figure 6-9). The organic matter had several peaks throughout the year, each coinciding with an influx of finer sediments.

During the 2001-2002 reporting period, site P8 exhibited a sediment composition different from the current reporting period. Finer sediments were the dominant sediment type with pulses of sand appearing every few months.

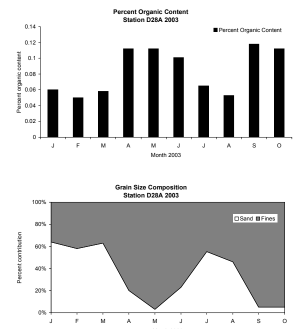

Figure 6-10 Sediment organic content and grain size at Station D28A during 2003

Site D28A: Sediment Composition

Finer sediment usually dominated sediment at D28A, with the exception of the winter months (Figure 6-10). Higher percentages of organic matter occurred during the months with the highest percentages of fines.

During the 2001-2002 reporting period, this site exhibited similar sediment composition patterns as the 2003 reporting period.

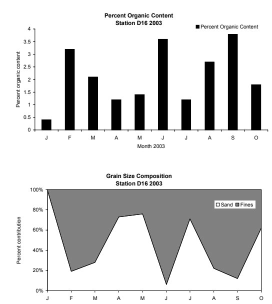

Figure 6-11 Sediment organic content and grain size at Station D16 during 2003

Site D16: Sediment Composition

Sediment characteristics at this site were very dynamic during 2003 (Figure 6-11). Consequently, the percentage of organic matter changed every few months. The higher percentages of organic matter coincided with the higher percentages of finer sediments.

During the 2001-2002 reporting period, site D16 was dominated by fines, with the exception of the spring and fall, when sand dominated the sediment composition at this site.

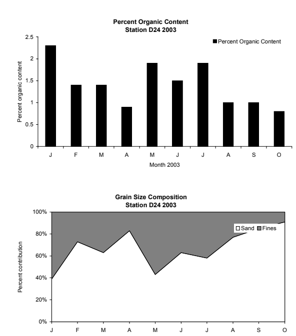

Figure 6-12 Sediment organic content and grain size at Station D24 during 2003

Site D24: Sediment Composition

Sand dominated the sediment at D24, except for one peak of finer sediments in January (Figure 6-12). The percent of organic matter at this site remained fairly stable during 2003 (ranging between 0.8% and 2.3%).

During the 2001-2002 reporting period, this site exhibited similar sediment composition patterns as the 2003 reporting period.

Site D4: Sediment Composition

Sand dominated the sediment at D4 during 2003, with the exception of January and May (Figure 6-13). The percent of organic matter at this site was high for most of the year, except in cases where the percent of fines increased.

During the 2001-2002 reporting period, this site was dominated by finer sediments from January to July 2001. From June 2001 to December 2002 the sediment composition was dominated by sand.

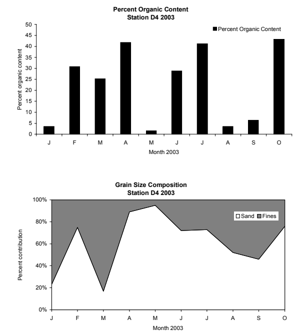

Figure 6-13 Sediment organic content and grain size at Station D4 during 2003

Site D6: Sediment Composition

Finer sediments were the dominant sediment at D6 (Figure 6-14). Organic matter at this site was stable during 2003 (average 4.3%).

During the 2001-2002 reporting period, this site exhibited similar sediment composition patterns as the 2003 reporting period.

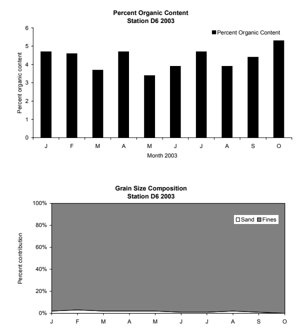

Figure 6-14 Sediment organic content and grain size at Station D6 during 2003

Site D7: Sediment Composition

Finer sediments were the dominant type at D7 (Figure 6-15). The organic matter at this site was stable throughout the study period (average 3.9%).

During the 2001-2002 reporting period, this site exhibited similar sediment composition patterns as the 2003 reporting period.

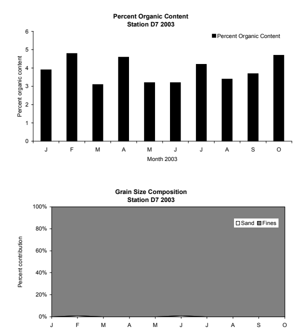

Figure 6-15 Sediment organic content and grain size at Station D7 during 2003

Site D41: Sediment Composition

Finer sediments usually dominated the sediment at D41 with the exception of two spikes during March and June, when sand was the dominant sediment type (Figure 6-16). The organic matter at this site was relatively stable with lower values occurring during the spring and summer months.

During the 2001-2002 reporting period, site D41 exhibited similar sediment composition patterns as the 2003 reporting period.

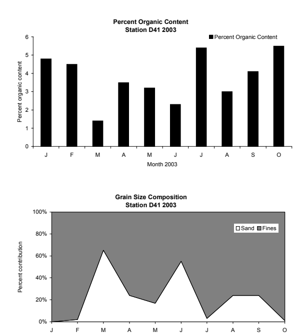

Figure 6-16 Sediment organic content and grain size at Station D41 during 2003

Site D41A: Sediment Composition

Finer sediments dominated the sediment at D41A (Figure 6-17). The percent organic matter at this site was stable (average 3.7%).

During the 2001-2002 reporting period, this site exhibited similar sediment composition patterns as the 2003 reporting period.

Summary

The benthic monitoring program is designed to document the distribution, diversity and abundance of benthic organisms in the upper San Francisco Estuary. The monitoring program collects a large number of organisms, but a relatively small number of species. All organisms collected during 2003 fell into eight phyla: Annelida, Arthropoda, Chordata, Cnidaria, Mollusca, Nemertea, Nematoda, and Platyhelminthes. Of these eight phyla, Annelida, Arthropoda and Mollusca constituted 99.4% of the organisms collected during the study period. Ten species represent 90% of all organisms collected during this period. These species are: (1) the amphipods, *Americorophium stimpsoni, Americorophium spinicorne, Corophium alienense, Monocorophium acherusicum*, *Gammarus daiberi* and *Ampelisca abdita*; (2) the cumacean, *Nippoleucon hinumensis*; (3) the aquatic oligochaete, *Varichaetadrilus angustipenis*; and (4) the Asian clams, *Potamocorbula amurensis* and *Corbicula fluminea*.

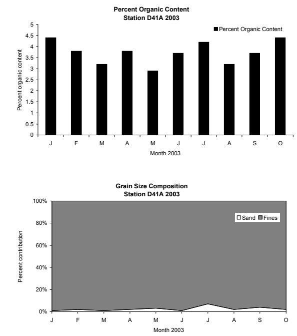

Figure 6-17 Sediment organic content and grain size at Station D41A during 2003

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[APHA] American Public Health Association, American Waterworks, and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. Washington, D.C.: American Public Health Association, 10.60-10.74.

[ASTMa] American Society of Testing and Materials, 2000. *Soil and Rock (I): D420 - D5779,* Vol. 04.08: protocol D422

[ASTMb] American Society of Testing and Materials, 2000. *Soil and Rock (I): D420 - D5779,* Vol. 04.08: ASTM protocol D2974 method C.

[DWR] California Department of Water Resources, 2001. *Water Quality Conditions in the Sacramento-San Joaquin Delta during 1996*.

Hymanson, Z., D. Mayer, J. Steinbeck, 1994. Long-Term Trends in Benthos Abundance and Persistence in the Upper Sacramento-San Joaquin Estuary. Summary Report: 1980-1990. *Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38*. California Department of Water Resources, Sacramento California.

Markmann, C, 1986. *Benthic Monitoring in the Sacramento-San Joaquin Delta. Results from 1975 through 1981. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Technical Report 12*. California Department of Water Resources, Sacramento California.

[SWRCB] State Water Resources Control Board. 1999. *Water Rights Decision 1641 for the Sacramento-San Joaquin Delta and Suisun Marsh*. Sacramento, California.

Figure 6-1 Location of 10 Environmental Monitoring Program benthic sampling sites

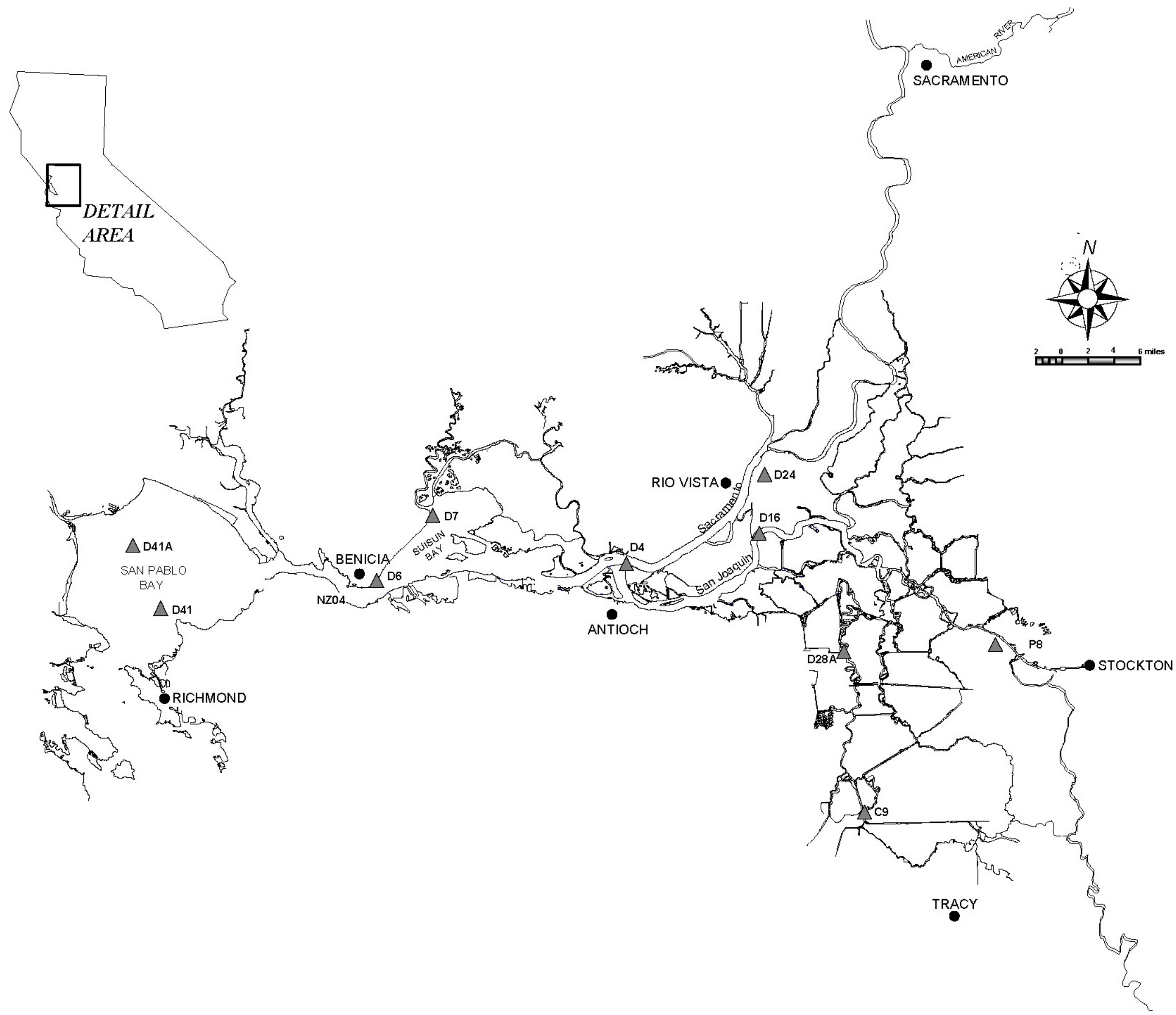


Figure 6-2 Total contribution by phyla for all stations during 2003

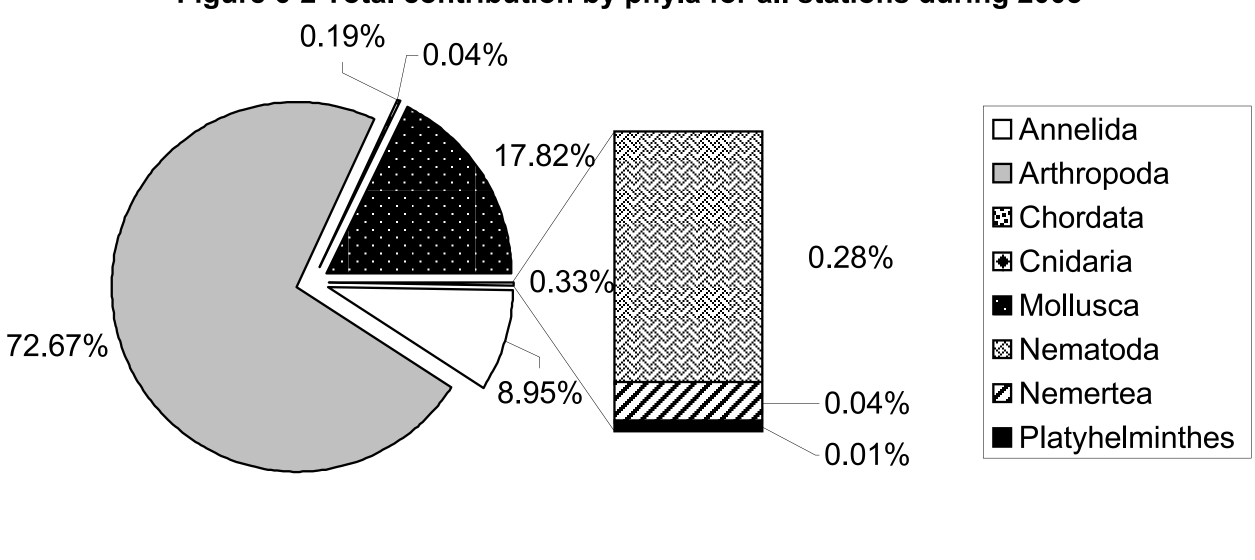
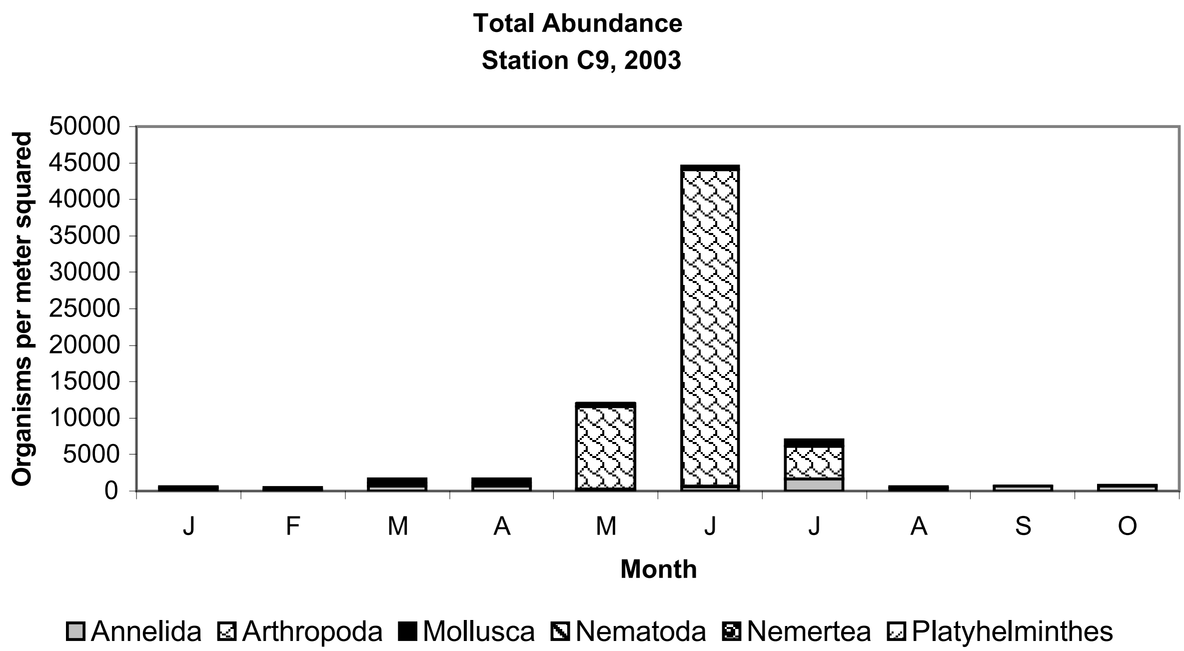


Figure 6-3 Benthic abundance at stations C9 and P8, 2003



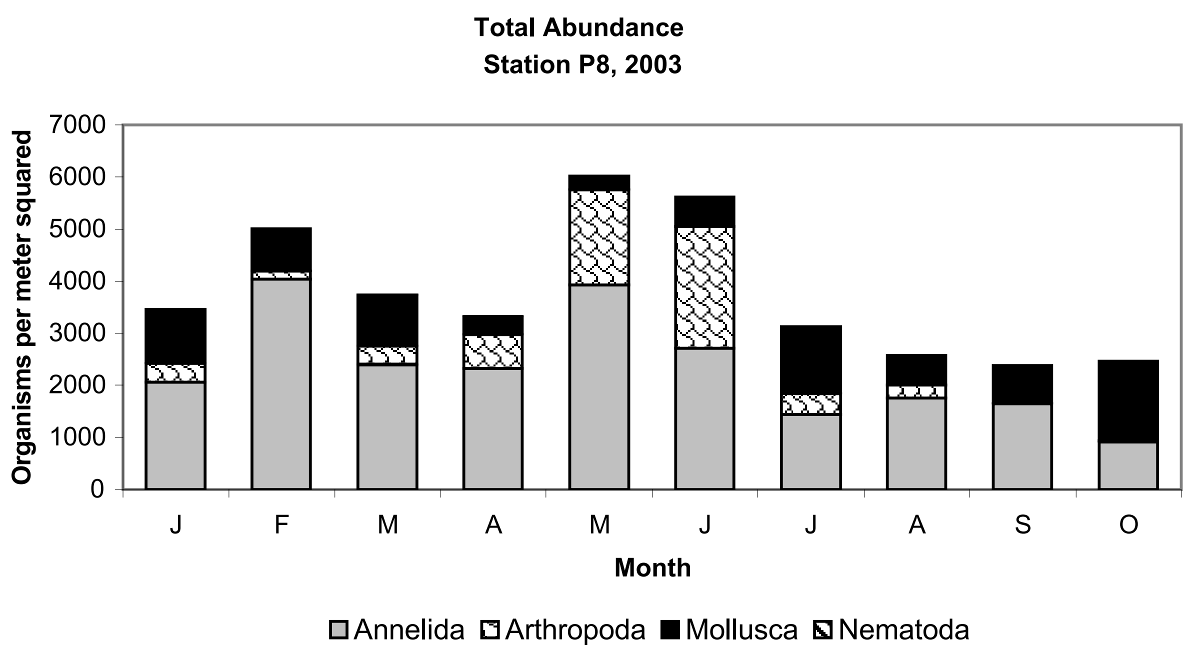
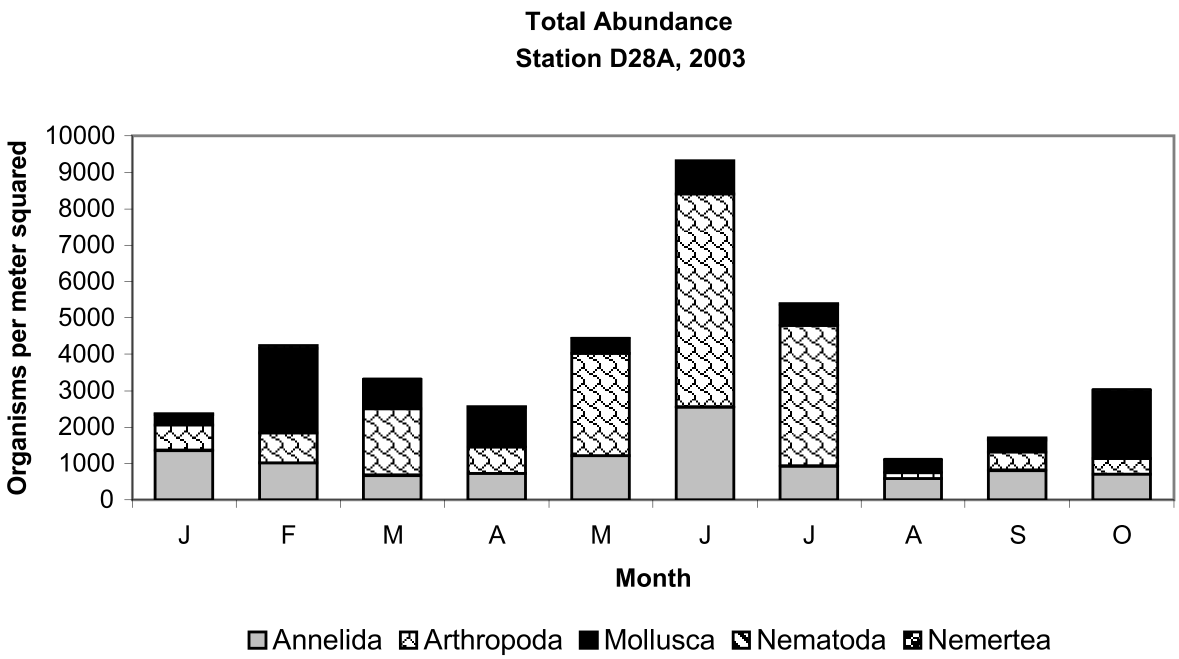


Figure 6-4 Benthic abundance at stations D28A and D16, 2003



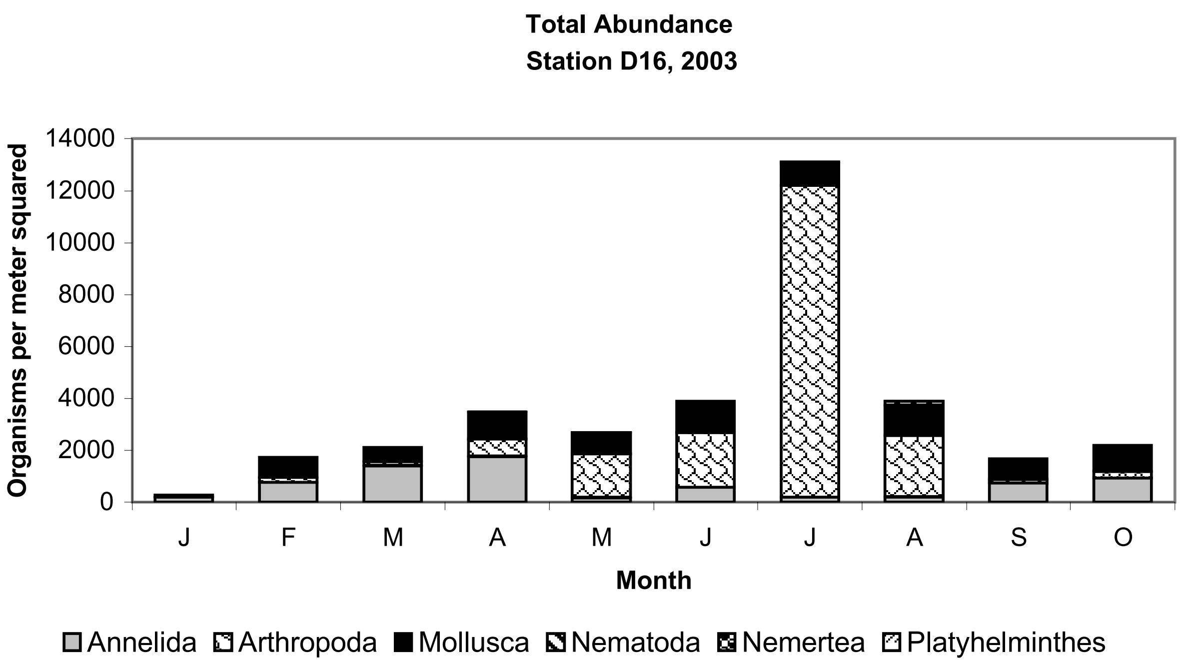
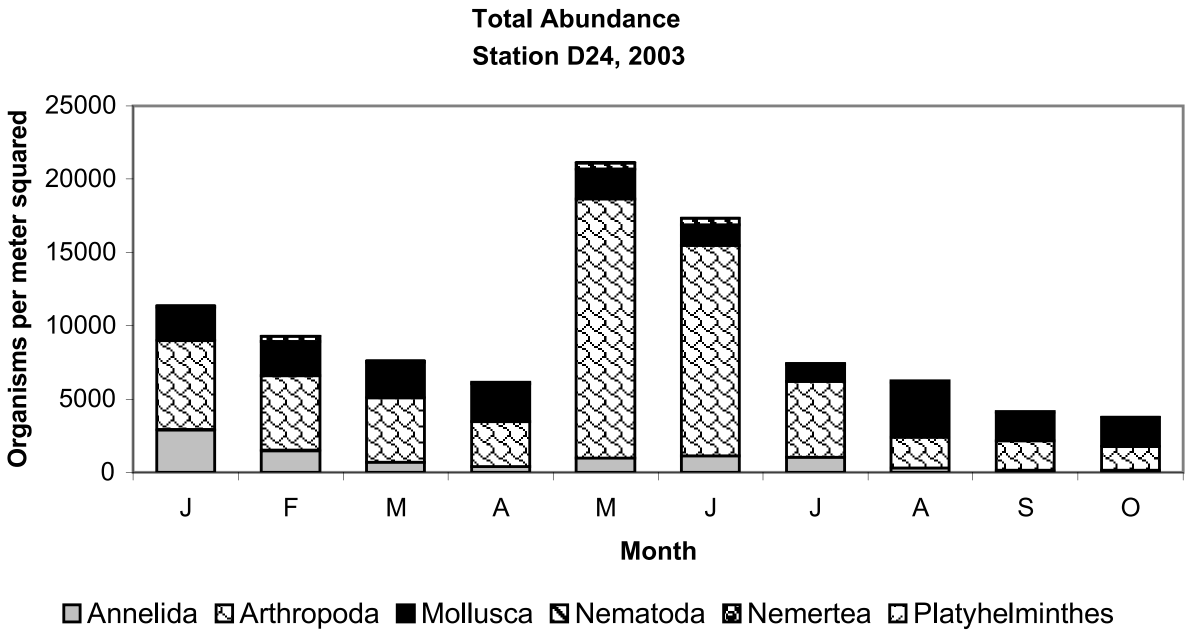


Figure 6-5 Benthic abundance at stations D24 and D4, 2003



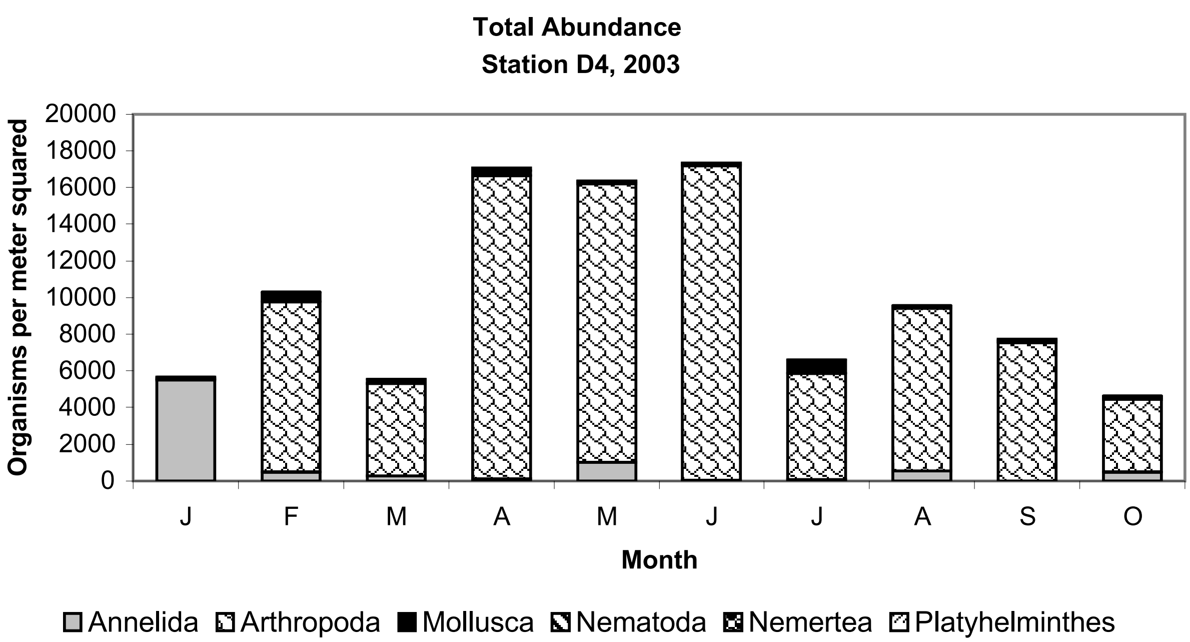
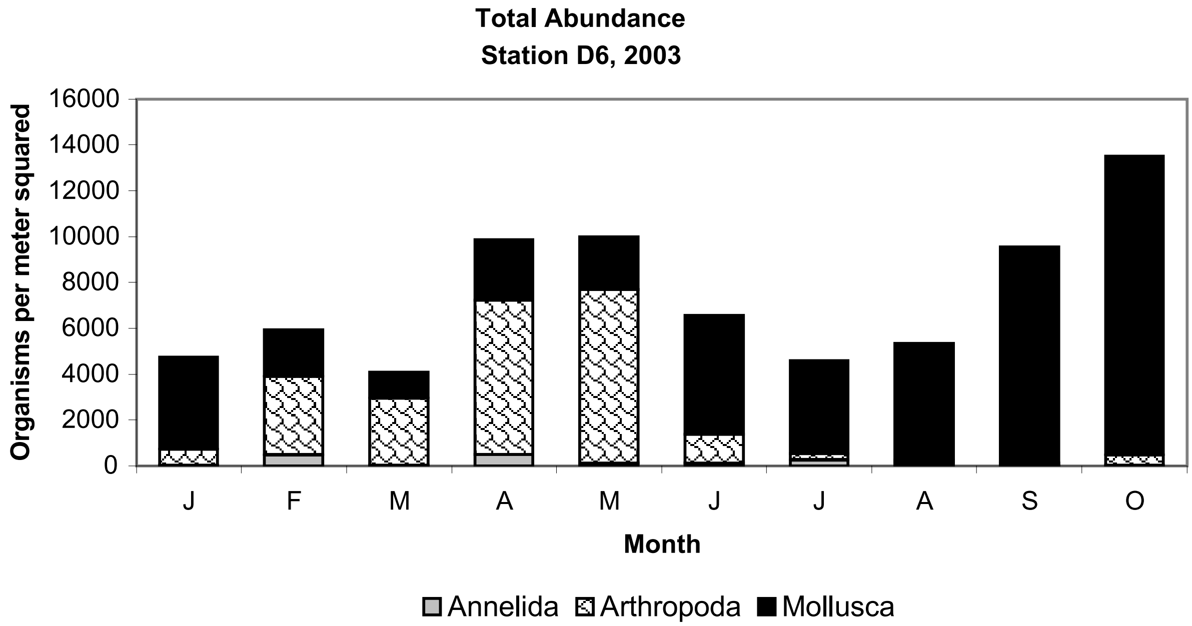


Figure 6-6 Benthic abundance at stations D6 and D7, 2003



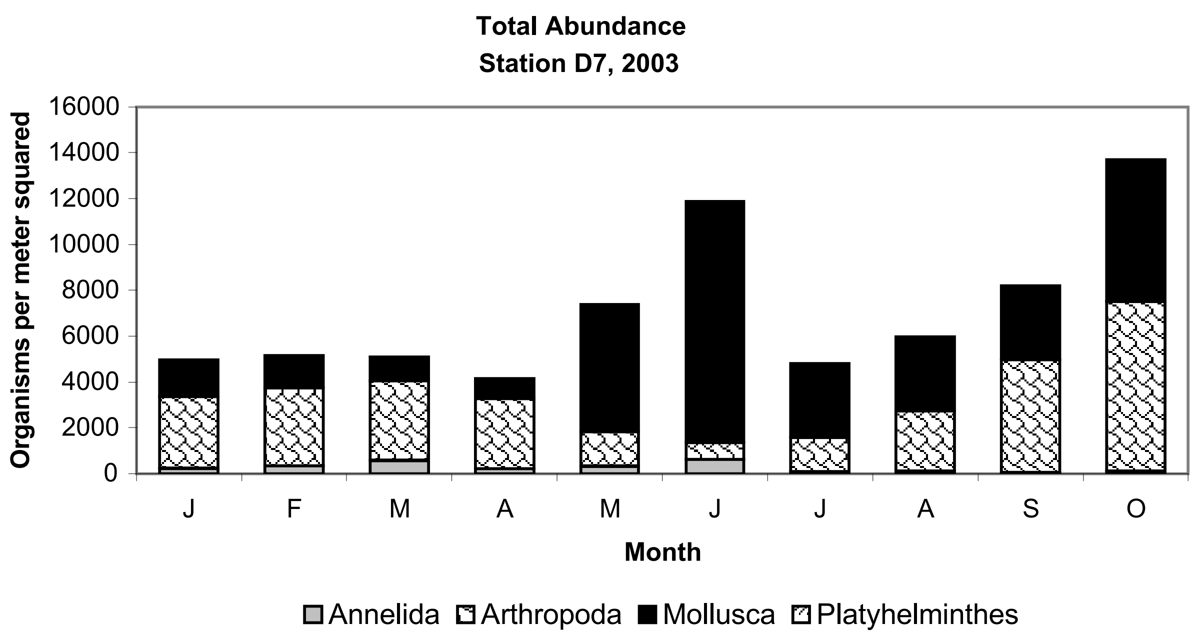
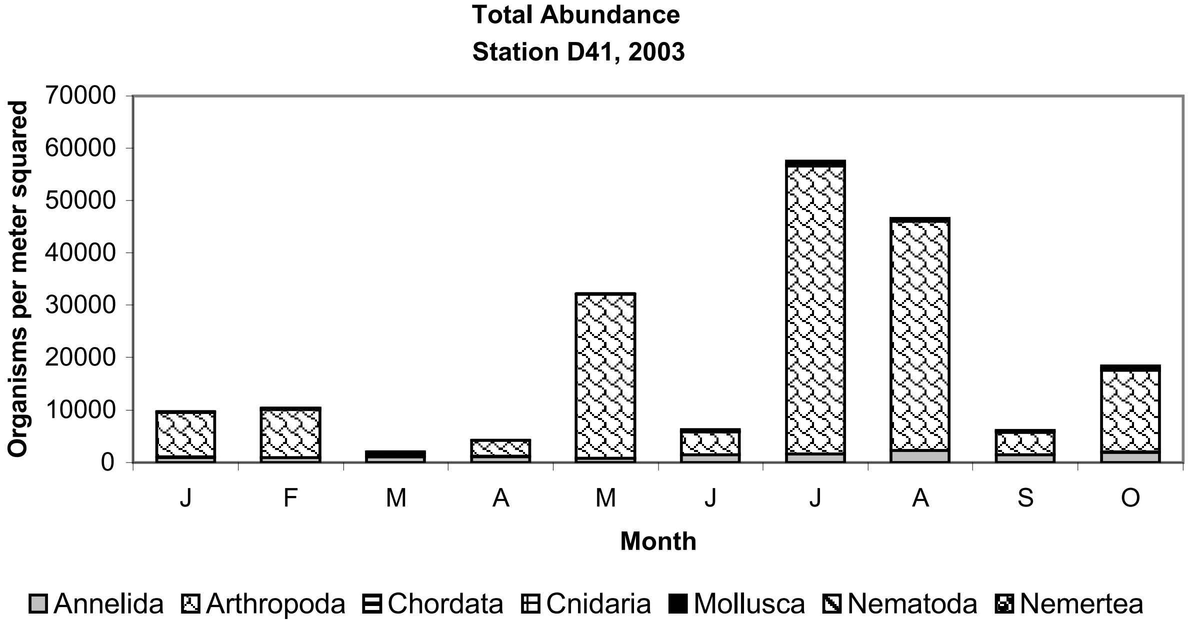


Figure 6-7 Benthic abundance at stations D41 and D41A, 2003



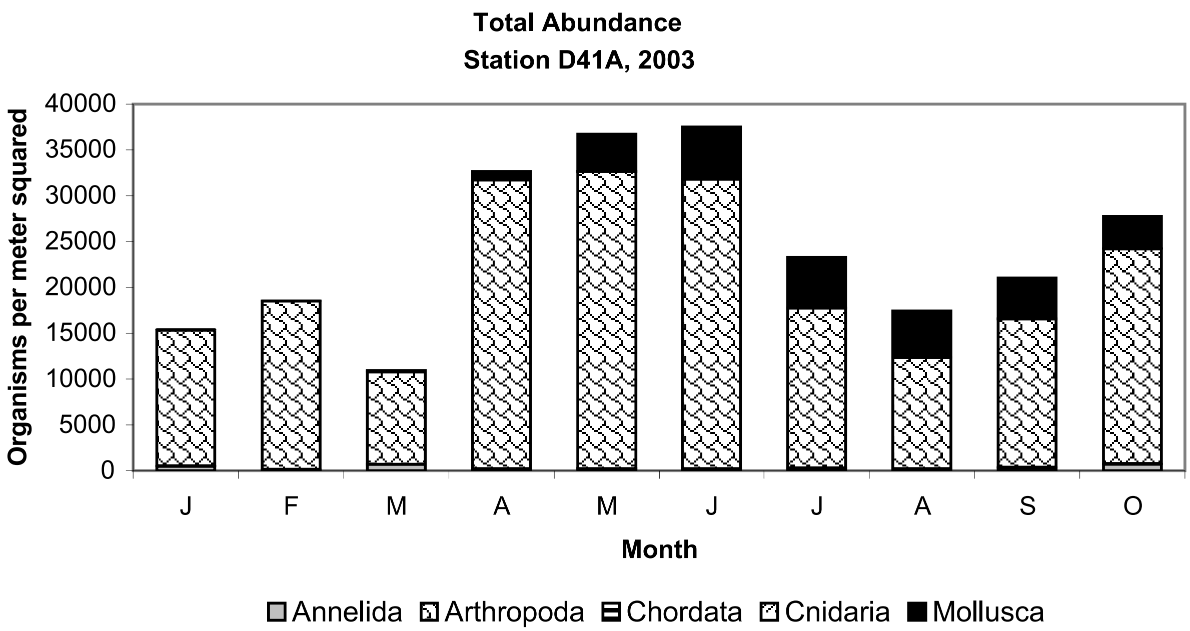
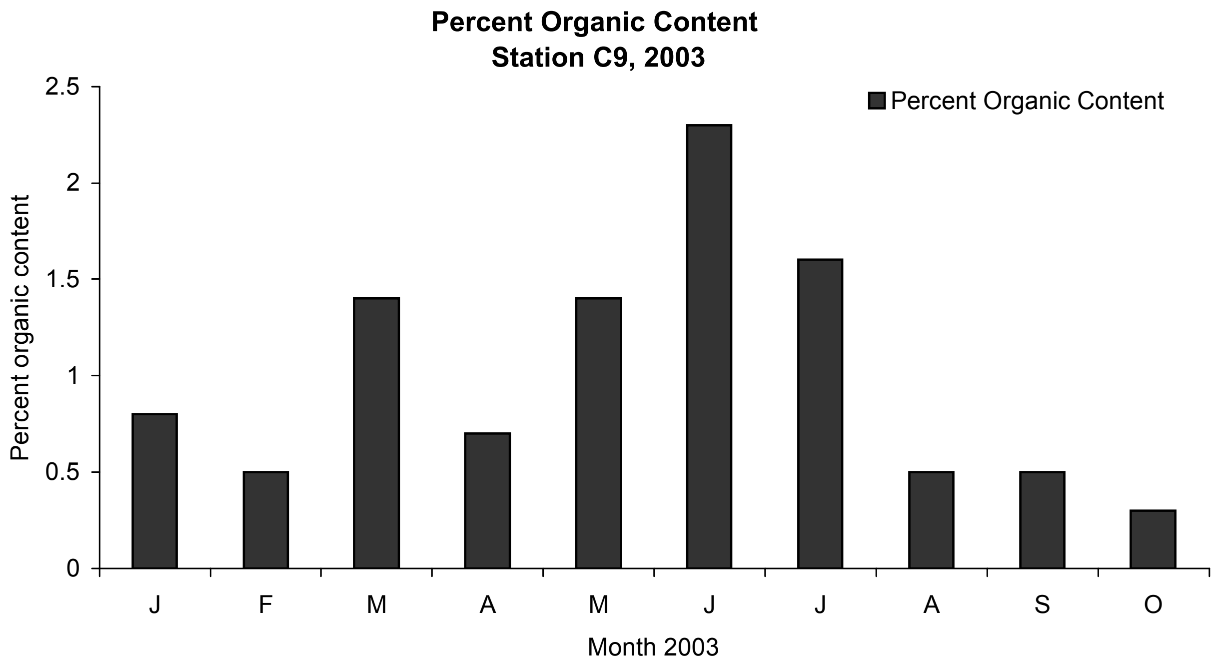


Figure 6-8 Sediment organic content and grain size at Station C9 during 2003



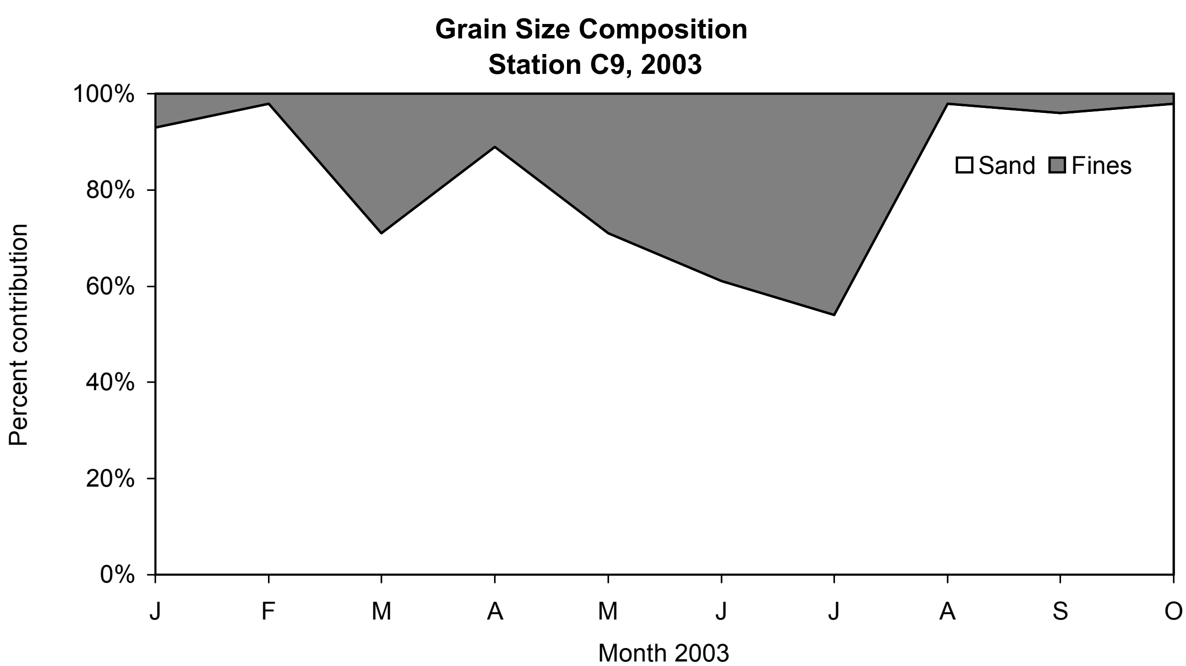
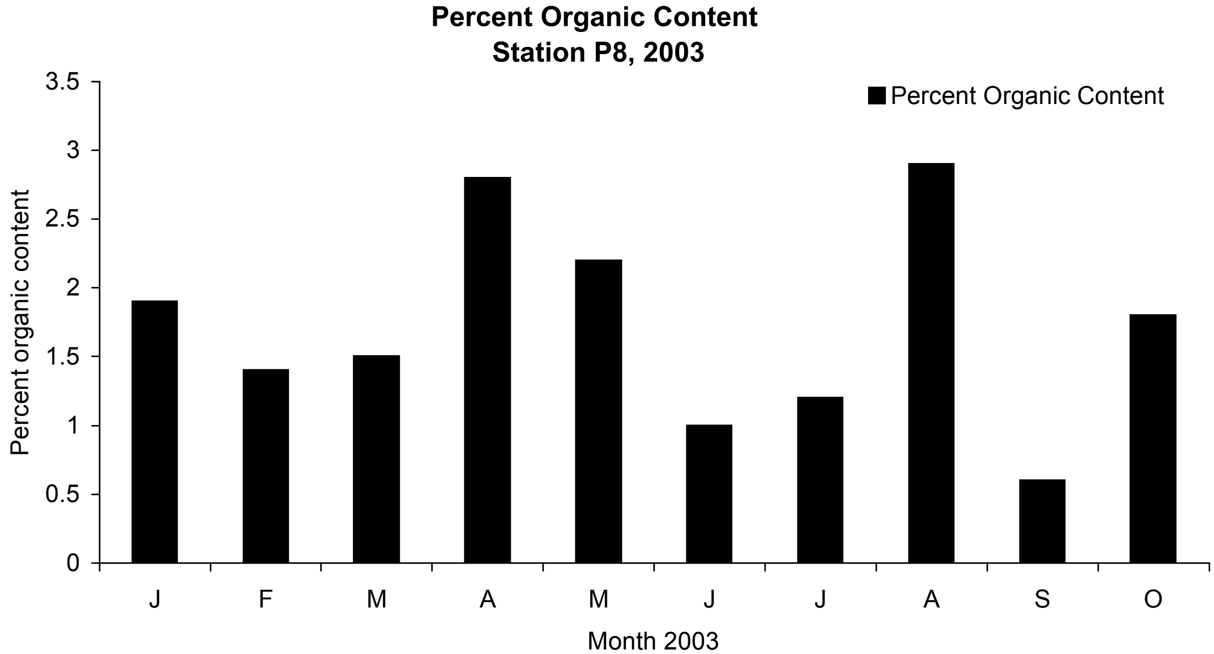


Figure 6-9 Sediment organic content and grain size at Station P8 during 2003



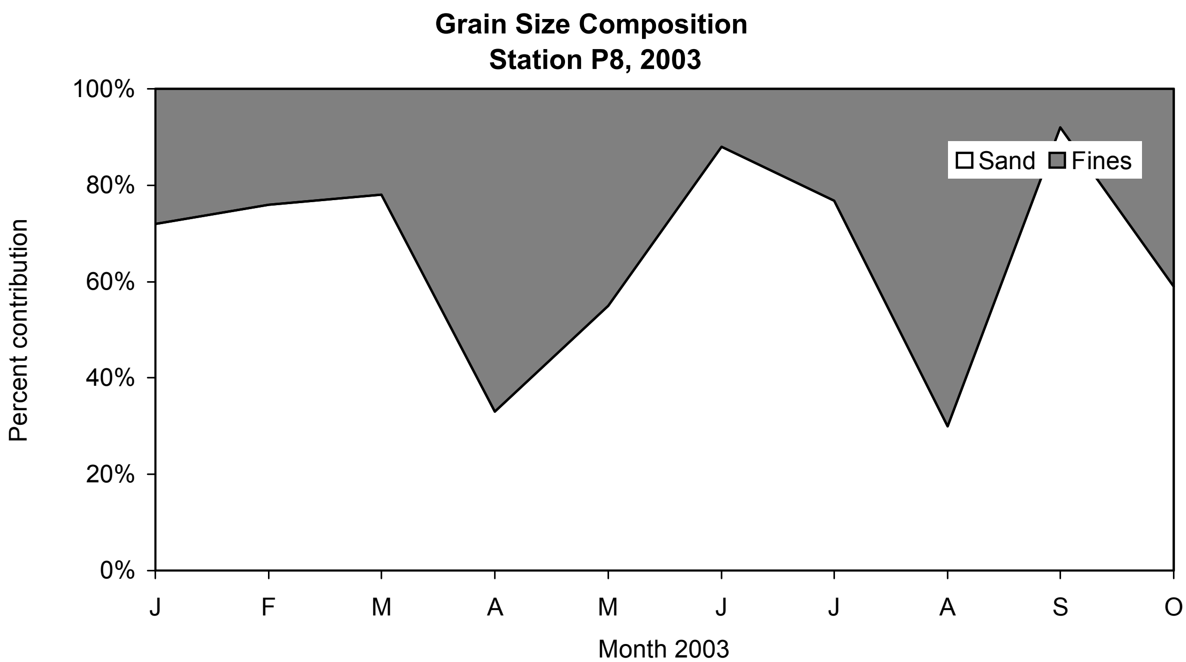
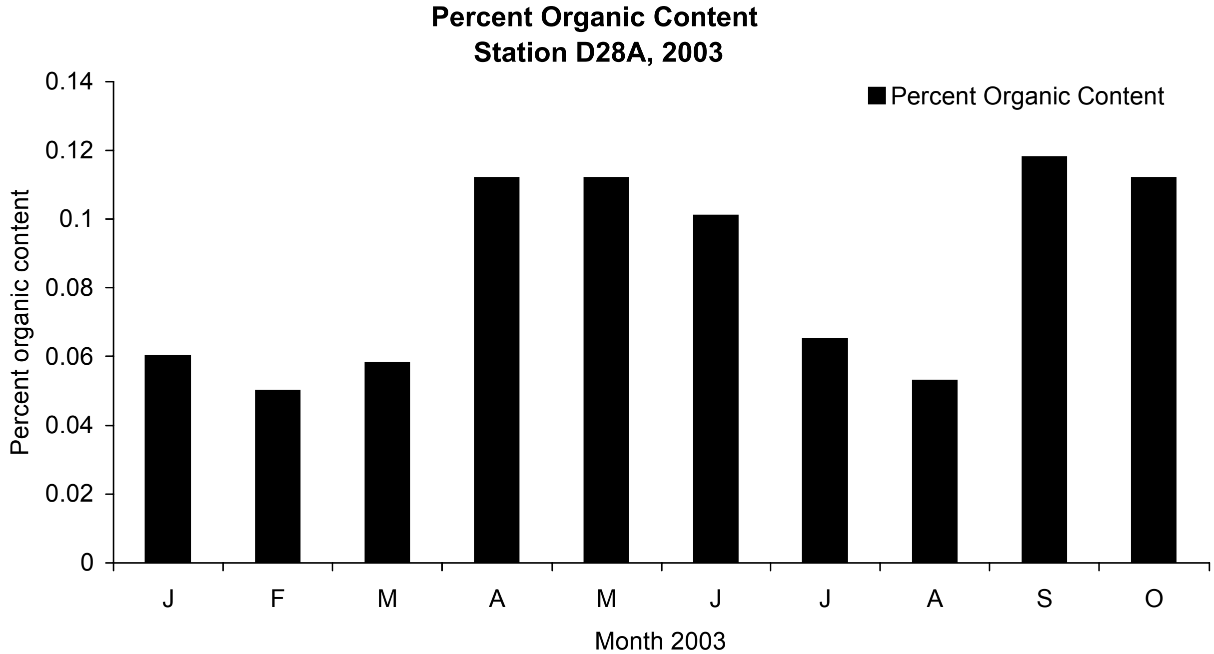


Figure 6-10 Sediment organic content and grain size at Station D28A during 2003



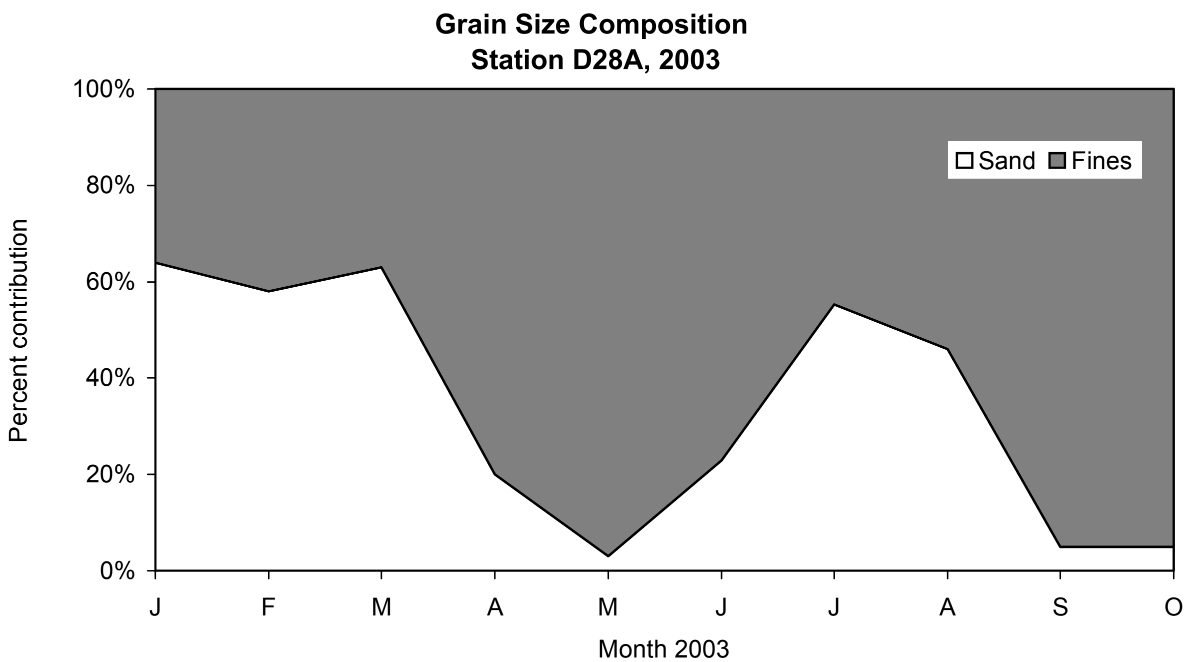
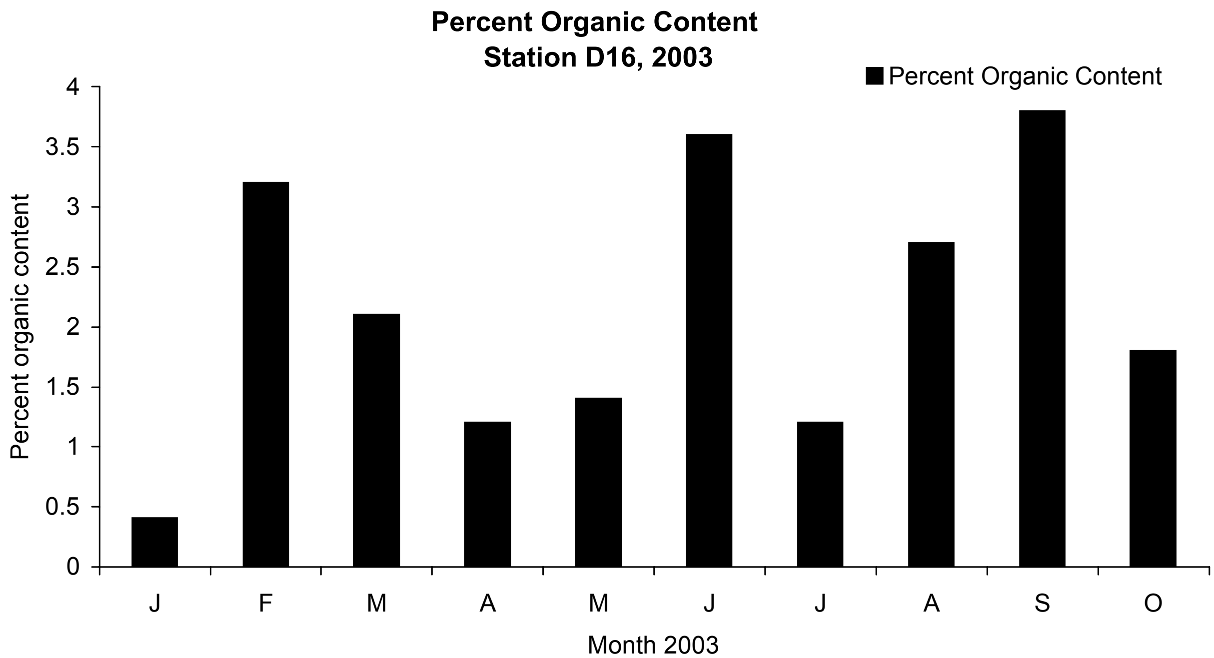


Figure 6-11 Sediment organic content and grain size at Station D16 during 2003



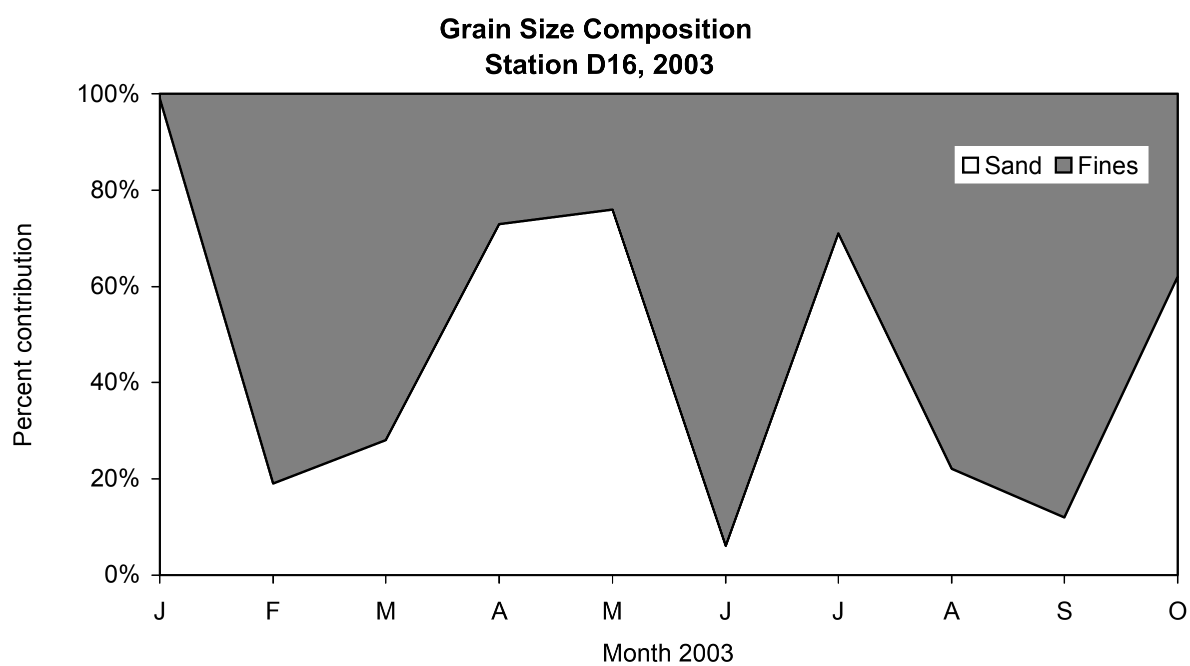
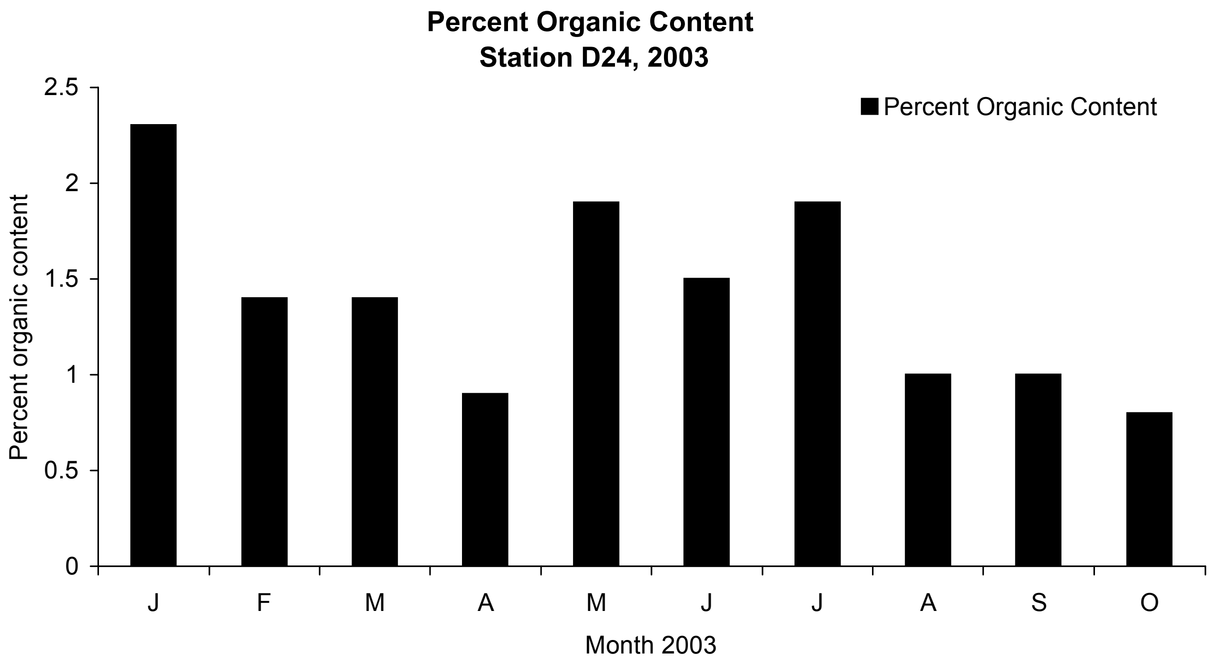


Figure 6-12 Sediment organic content and grain size at Station D24 during 2003



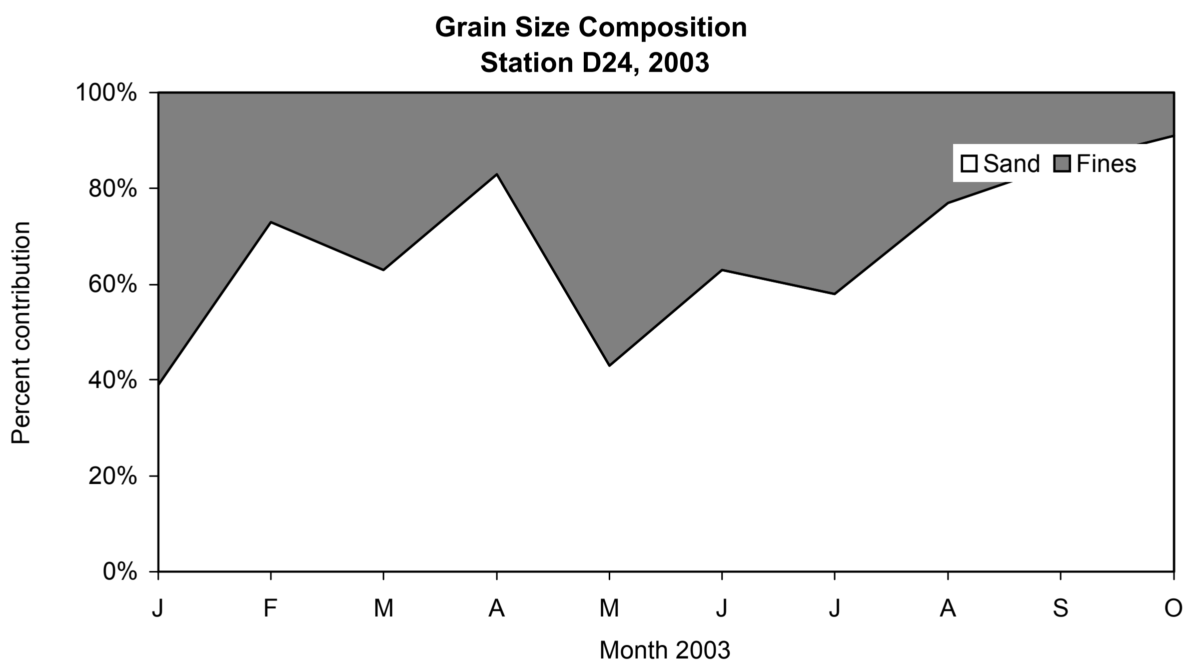
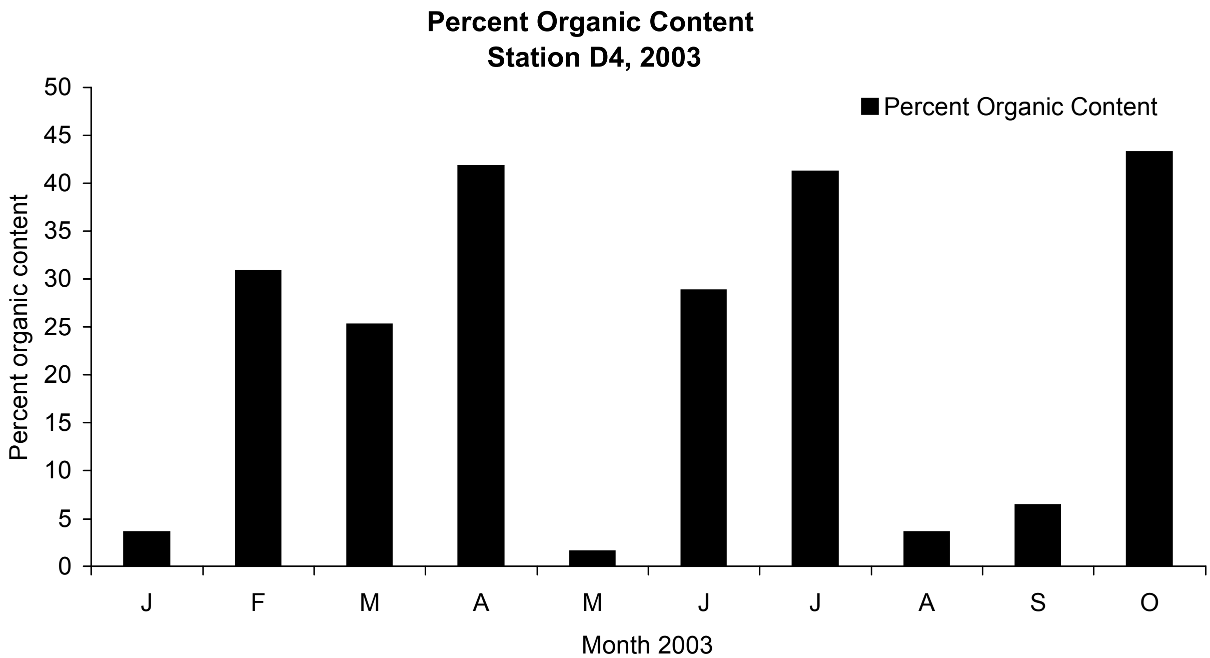


Figure 6-13 Sediment organic content and grain size at Station D4 during 2003



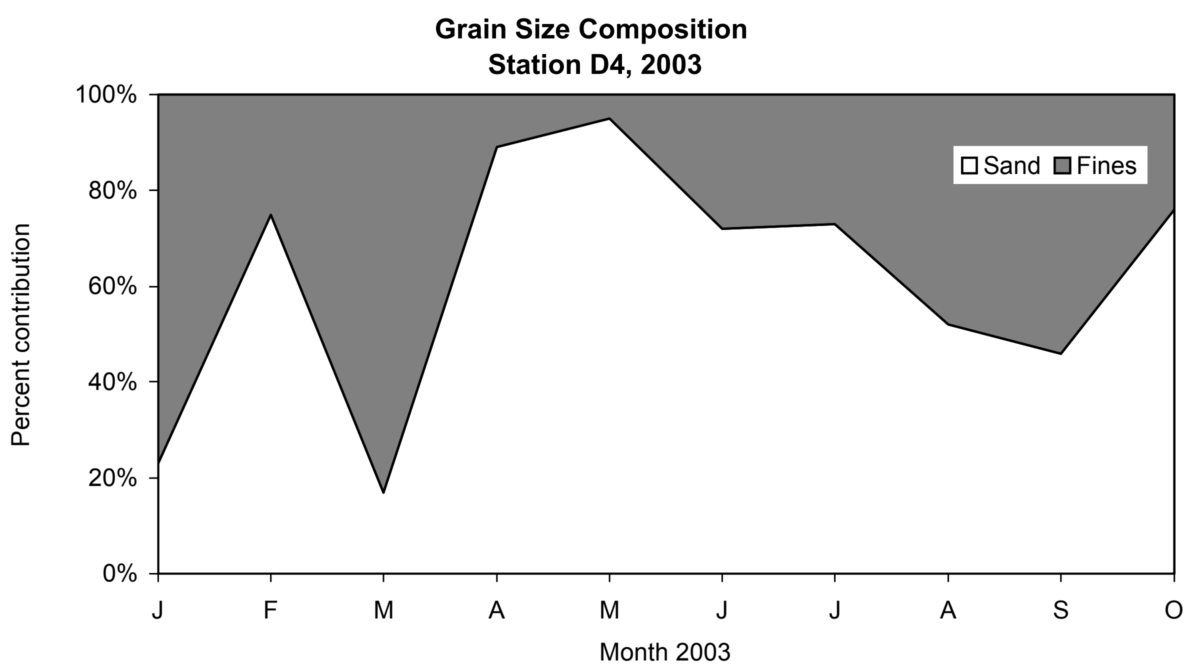
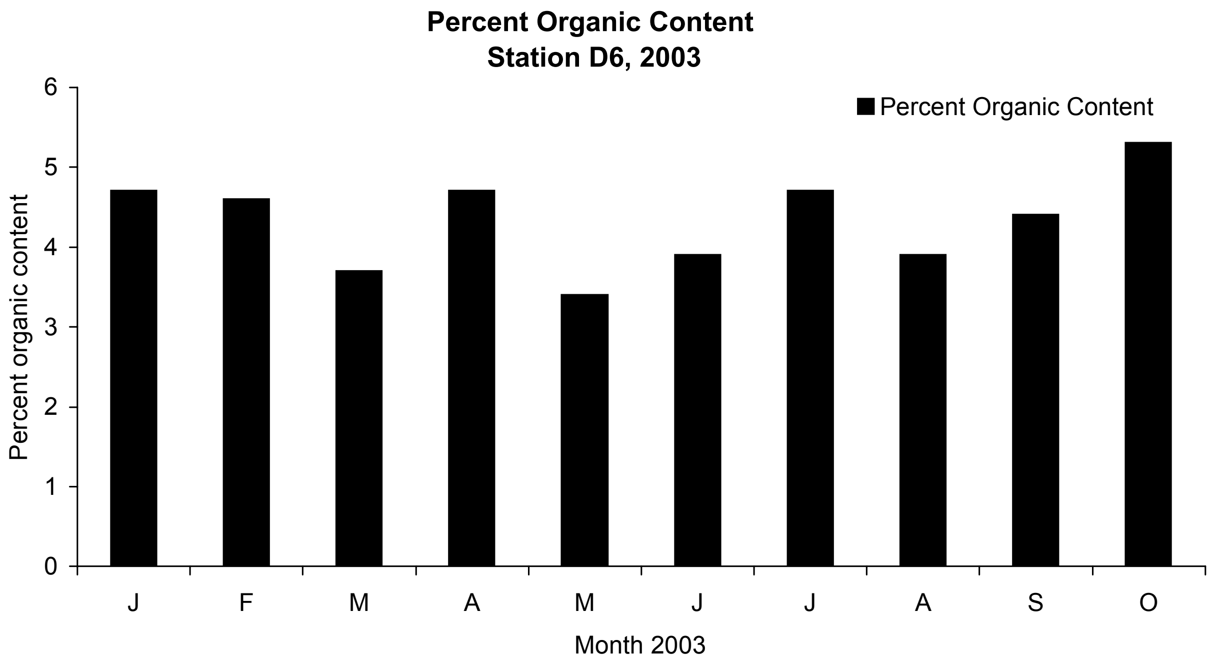


Figure 6-14 Sediment organic content and grain size at Station D6 during 2003



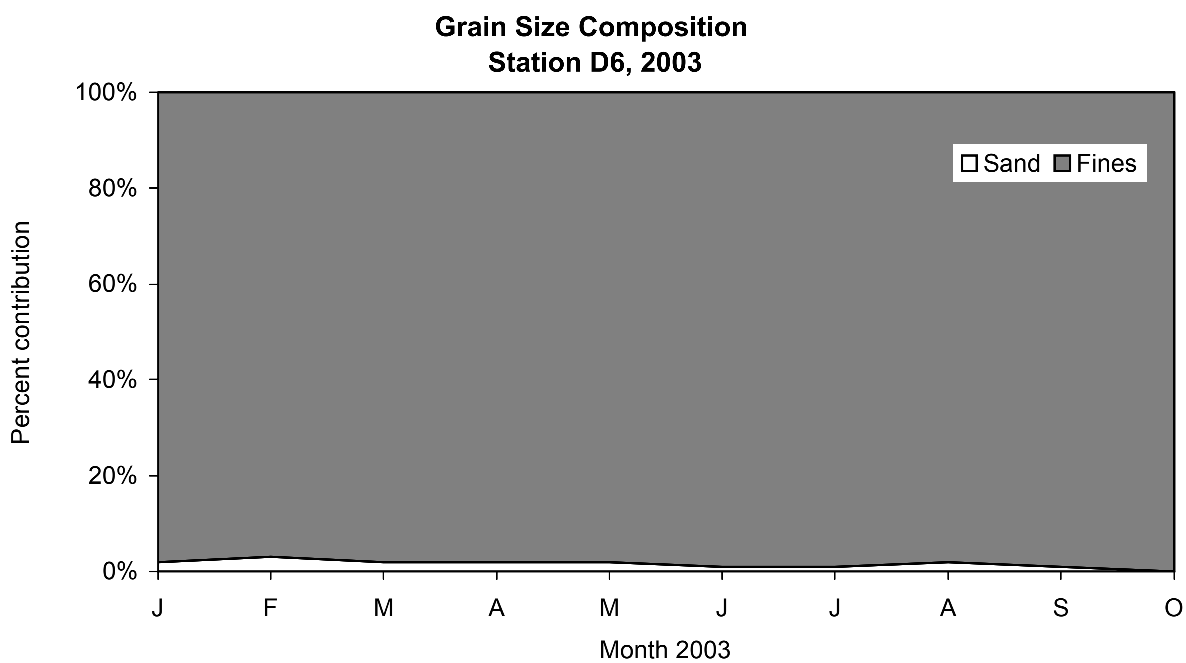
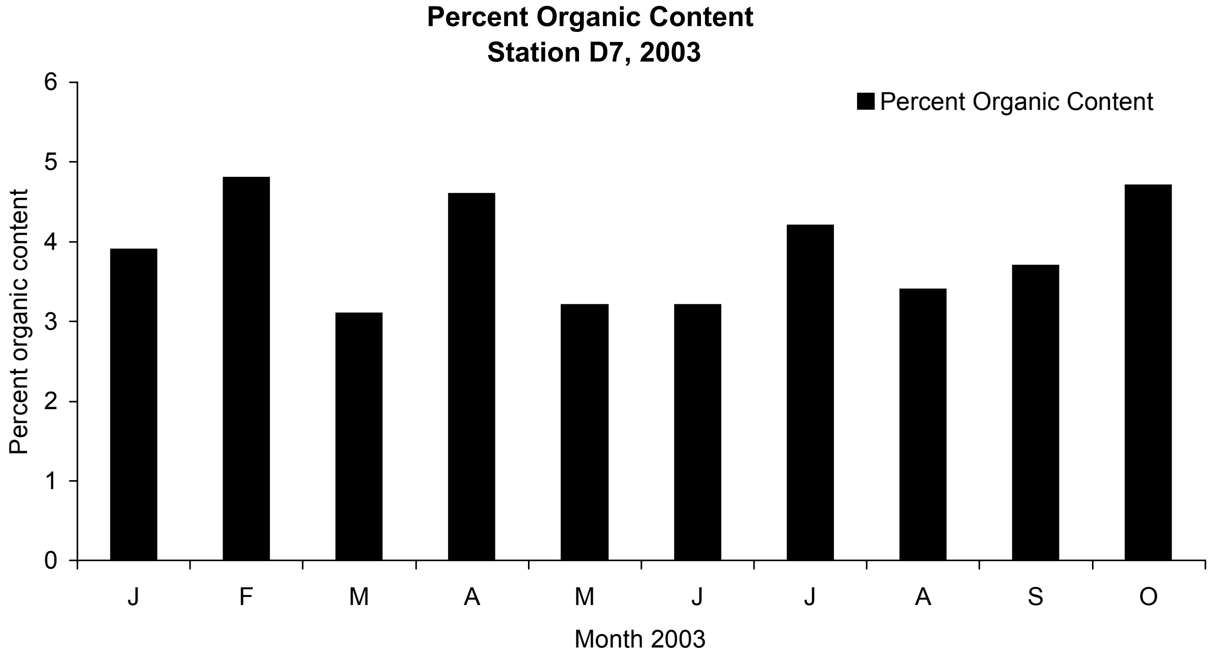


Figure 6-15 Sediment organic content and grain size at Station D7 during 2003



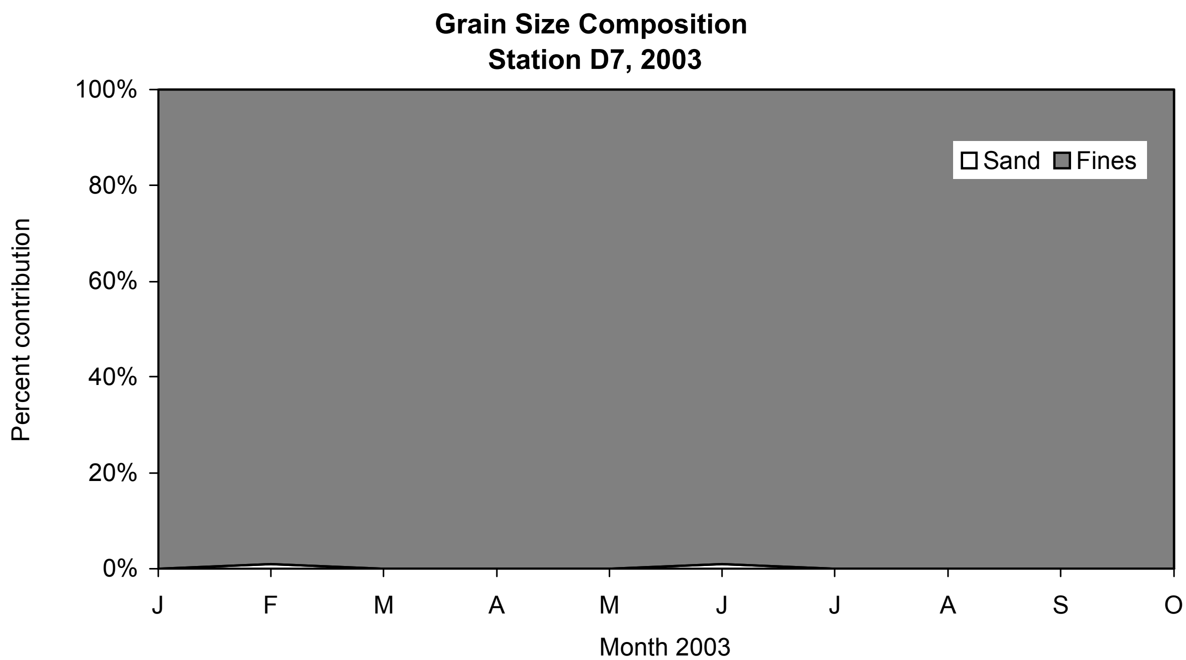
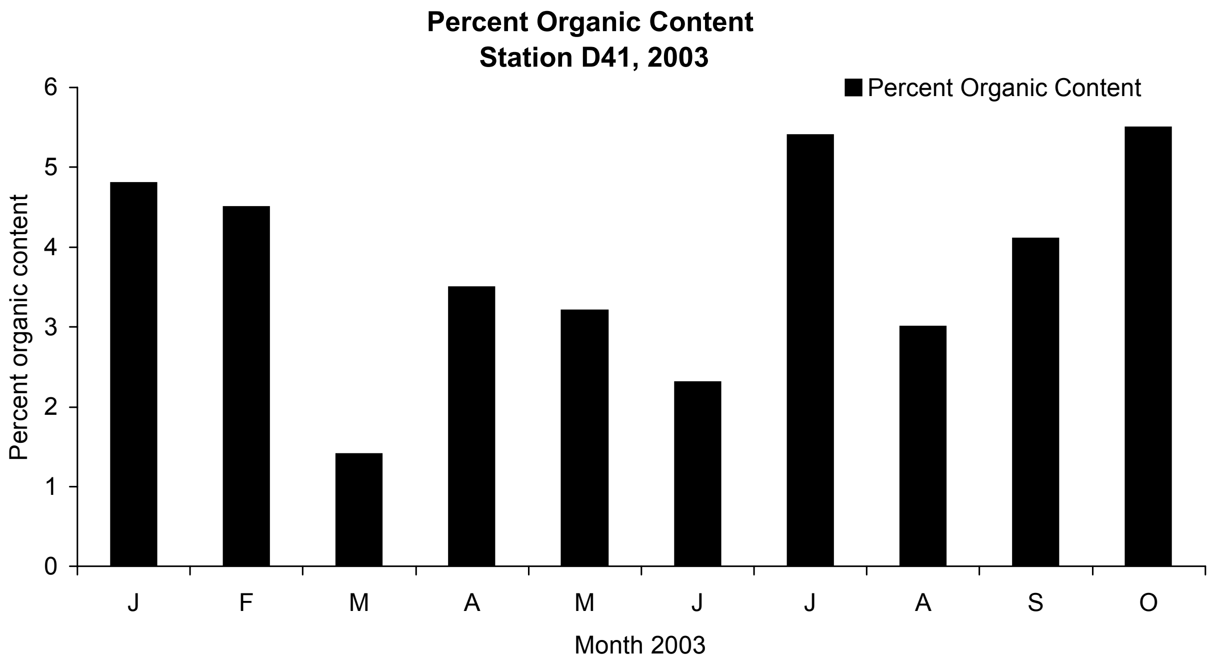


Figure 6-16 Sediment organic content and grain size at Station D41 during 2003



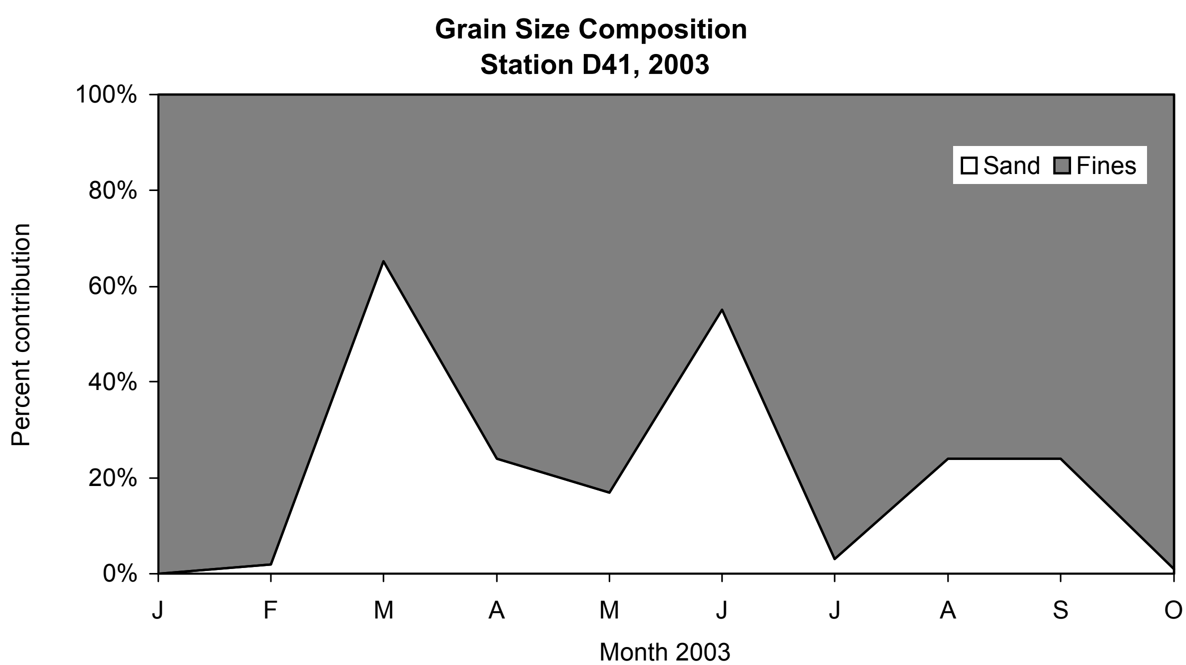
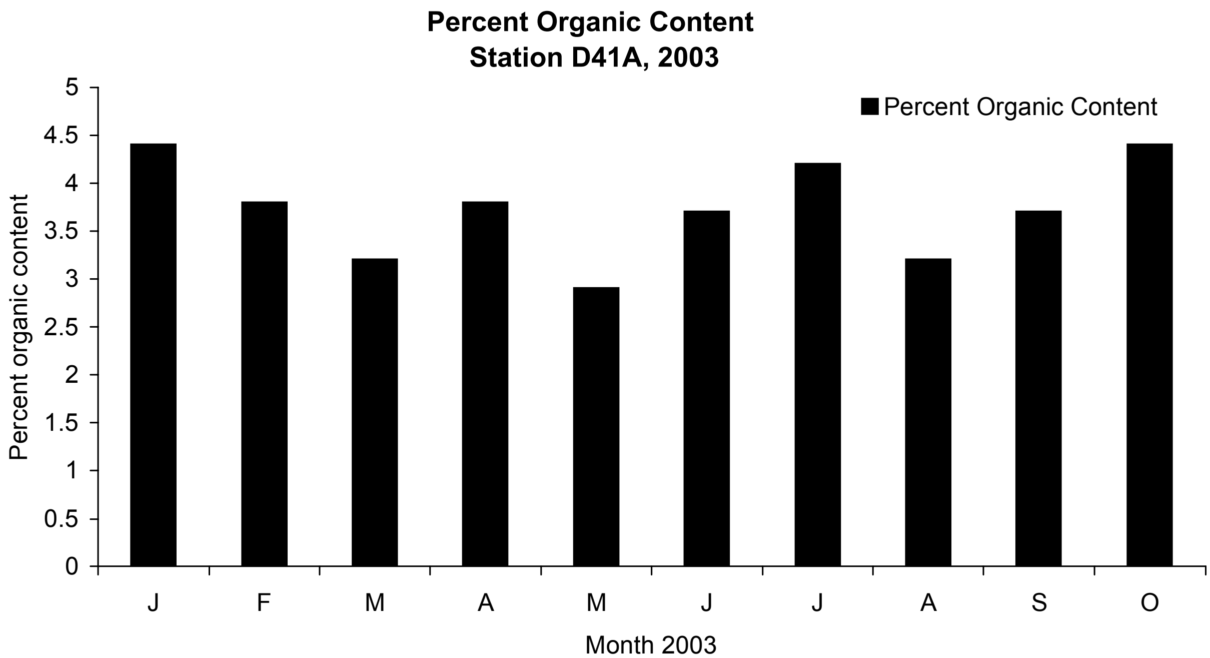


Figure 6-17 Sediment organic content and grain size at Station D41A during 2003



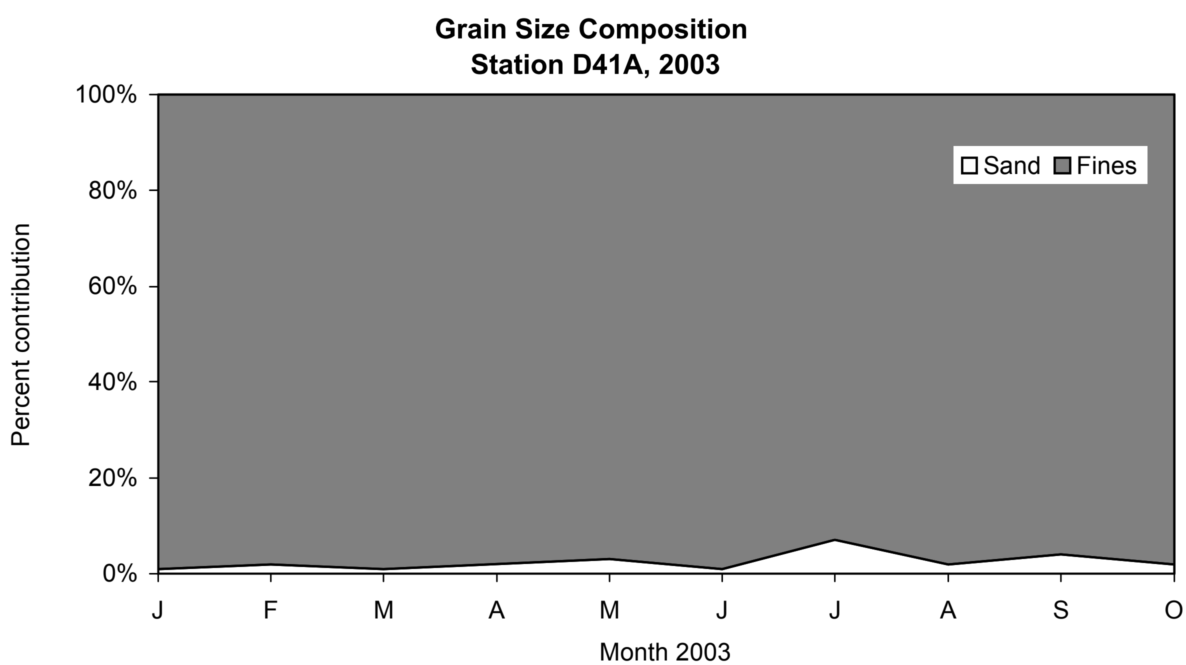


Table 6-1 Macrobenthic monitoring station characteristics, 2003

Station Region	Latitude Longitude	Substrate Composition	Approx. Salinity Range (µS/cm)
C9 Delta-Old River	37°49'50" 121°33'09"	Consistent. Over 90% sand.	200-800
P8 Delta San Joaquin River	37°58'42" 121°22'55"	Consistent. High sand content (60%)	175-750
D28A Delta Old River	37°58'14" 121°34'19"	Mixed composition of sand and fines	200-350
D16 Delta San Joaquin River	38°05'50" 121°40'05"	Consistent. Mostly fines with some organic materials	130-500
D24 Delta Sacramento River	38°09'27" 121°41'01"	Consistent. High sand content (80%).	200-1,200
D4 Delta Sacramento River	38°03'45" 121°49'10"	Mixed composition of sand, fines, and organic materials.	130-8,000
D6 Suisun Bay	38°02'40" 122°07'00"	Fairly equal mixture of sand and fines	135-30,000
D7 Grizzly Bay	38°07'02" 122°02'19	Consistent. Mostly Fines with some organic materials.	200-20,000
D41 San Pablo Bay	38°01'50" 122°22'15"	Consistent. High content of fine material (87%)	20,000-45,000
D41A San Pablo Bay	38°03'75" 122°24'40"	Consistent. High content of fine material (90%)	30,000-44,000

Table 6-2 New species, 2003

Phylum	Genus Species	Date	Station
Annelida	*Aricidea* species *A*	February 2003	D41
Annelida	*Tharyx parva*	February 2003	D41
Annelida	*Pholoides aspera*	February 2003	D41
Arthropoda	*Tipula* species *A*	February 2003	D24
Arthropoda	*Hygrobates* species *A*	February 2003	D24
Arthropoda	*Psychoda* species *A*	March 2003	D24
Arthropoda	*Neoplasta* species *A*	March 2003	D24
Annelida	*Arcteonais lomondi*	April 2003	C9
Arthropoda	*Simulium* species *A*	May 2003	D41A
Arthropoda	*Callianassa* species *A*	May 2003	D41
Arthropoda	*Cancer magister*	May 2003	D41
Arthropoda	*Ampithoe valida*	July 2003	D41
Arthropoda	*Monocorophium uenoi*	July 2003	D41, D41A
Annelida	*Pista pacifica*	September 2003	D41
Mollusca	*Melanochlamys diomedea*	September 2003	D41
Mollusca	*Macoma* species *A*	September 2003	D41